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Recommendations for the Implementation and Continued Refinement of a Comprehensive Monitoring Assessment and Research Program

Developed for CALFED

By

The CMARP Steering Committee

Serge Birk (CVPWA)

Randall Brown (DWR, IEP)

Larry Brown (USBR, IEP)

Bellory Fong (CALFED)

Rod Fujita (EDF)

Tom Grovhoug (LWA)

Bruce Herbold (EPA, IEP)

Perry Herrgesell (DFG, IEP)

Margaret Johnston (SFEI)

Laura King (SLMWA)

Marty Kjelson (USFWS, IEP)

Fred Nichols (USGS)

Peter Rhoads (MWD)

Larry Smith (USGS, IEP)

Peter Stine (USGS)

Program Manager: Leo Winternitz (DWR, IEP)

Draft Report

November 19, 1998

Date: November 19, 1998

To: CALFED Management and Agency Management Reviewers

From: CMARP Steering Committee

Subject: Draft Comprehensive Monitoring, Assessment and Research Program (CMARP) Report

Attached for your review is the initial draft of the Comprehensive Monitoring, Assessment and Research Program report. The report seeks to describe the progress that has been made and the recommendations that have been proposed in the effort to achieve the goals set out in the *Proposal for the Development of a Comprehensive Monitoring Assessment and Research Program* of April 24, 1998 and subsequently accepted by the CALFED Policy Team.

These goals are:

- work with CALFED partners to refine program goals and objectives;
- develop conceptual models in each of the program elements;
- design a comprehensive monitoring, assessment and research program;
- identify key research questions and establish a research-support process, and
- propose an institutional framework

The recommendations in this report were developed based on the information needs of the eight CALFED programs (Ecosystem Restoration, Water Quality, Delta Levees, Storage, Conveyance, Water Transfers, Water Use Efficiency and Watershed Management) and supporting programs (Category III and Conservation Strategy). The monitoring and research recommendations address those gaps in our knowledge associated with the four problem areas in the Bay-Delta system identified by CALFED (Ecosystem Quality, Water Supply Reliability, Water Quality and Levee System Integrity). Over thirty work teams were convened to discuss and synthesize our knowledge of the relevant system processes, interactions and stressors, and to develop recommendations for monitoring and research programs that are consistent with meeting CALFED's goals and objectives. The CMARP Steering Committee has summarized the work team recommendations in this report.

The complete technical reports from each of the work teams will be available as appendices when the report is distributed for public review in December 1998. If you are interested in reviewing the appendices now, they are available on the CMARP web site[1] or can be obtained as hard copies, as requested. Please contact Leo Winternitz at (916) 227-7548, (Lwintern@water.ca.gov) for more information.

Please review the draft report and provide us with your comments by 5:00 p.m., November 30th. Send all comments to Leo Winternitz at 3251 "S" Street, Sacramento, CA 95816.

Thank you for your interest and your assistance in helping improve the content and usefulness of this report.

[1] Address: HTTP://WWW. IEP.CA.GOV
Username: CMARP
Password: GNFSHNG

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Chapter I. EXECUTIVE SUMMARY

In April 1998, the CALFED Policy Group approved a joint San Francisco Estuary Institute, Interagency Ecological Program, U.S Geological Survey proposal to develop a Comprehensive Assessment, Monitoring and Research Program (CMARP) for CALFED and its member agencies. CALFED allocated $1.8 million to complete the project, with a final report due by January 31, 1999. The proposed CMARP addresses eight CALFED program elements and actions to be implemented over the next 30 years. The program elements are Long-term Levee Protection, Water Quality, Ecosystem Restoration, Water Use Efficiency, Water Transfers, Watershed, Delta Conveyance, and Storage. (See attachment __ for the complete CMARP proposal.)

This report contains programmatic recommendations for a long-term monitoring, assessment, and research program. Prior to a record of decision on CALFED's programmatic environmental impact report, early implementation tasks and additional program refinement are proposed. A data management and reporting process and organizational ingredients necessary to implement the program are proposed and the process by which the program was designed is documented. Technical appendices provide more detailed discussions of monitoring and research keyed to CALFED's needs.

Before describing CMARP, it is important to highlight the role of adaptive management in CALFED and the relationship between adaptive management and CMARP. All CALFED program elements are based on an adaptive management strategy, as presented in a draft CALFED report *Strategic Plan for Ecological Restoration.* The essential features of adaptive management involve casting actions in the form of hypothesis testing, collecting information, and revising the actions (hypotheses) as we learn from the actions (experiments). Although adaptive management appears relatively straightforward, in practice, there are few examples of large-scale restoration programs which have successfully embodied adaptive management practices (Walters, 1997). For CALFED to implement fully an adaptive management strategy, the following are some key requisites:

- Discipline – Management, staff, and stakeholders must develop an overall adaptive management strategy for each element and follow through.
- Funding – Adaptive management requires extensive and expensive data collection, interpretation, and dissemination over the life of the project.
- Communication – Information exchange among managers and scientists must be rapid, continuous, and effective.
- Decisiveness – Managers must make difficult decisions: decisions that will involve risk taking, because there is always some degree of uncertainty about the outcome.
- Coordination – There must be coordination among CALFED program elements and between other programs such as the Central Valley Project Improvement Act and the Sacramento and San Joaquin River Basins Comprehensive Study which may be taking similar actions.

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CMARP Tasks

The work tasks specified in the CMARP proposal were to:

1. refine CALFED goals, objectives and needs;
2. develop a conceptual framework for the CMARP program;
3. design a monitoring program;
4. develop a CALFED focused research program; and
5. develop an institutional framework for CMARP.

The CALFED program evolved considerably between the time the Policy Group approved the proposal and completion of the CMARP report. For example, an August 5, 1998 report, "Developing a Draft Preferred Program Alternative" solidified the concept of a 30-year project completed in stages. The first stage would begin in 2000 and last seven years. The November 1998 draft CALFED Phase II report expanded on the staging concept and helped narrow options for the preferred alternative. The evolving definition of the preferred alternative and actions to be taken in Stage I have affected development of CMARP in the following ways:

1. The report is a programmatic overview rather than a specific plan.
2. Where possible, the report includes likely Stage 1 actions such as new fish screens, flexible operations, and water-quality questions associated with the through-Delta alternative.

CMARP Structure to Develop Recommended Program

The three parties responsible for developing CMARP established an 18-person Steering Committee consisting of agency and stakeholder scientists and co-chaired by Interagency Ecological Program, San Francisco Estuary Program, and U.S. Geological Survey representatives. The Steering Committee appointed a Chief of Staff and a small staff to facilitate the work. Most of the technical work was accomplished by 30 teams, which included more than 250 agency and stakeholder representatives.

CMARP ELEMENTS

The proposal to develop CMARP was based on completion of the five tasks listed above. The activities under each task are discussed in the following sections and include, where appropriate, references to likely early implementation and Stage 1 actions.

Task 1: Refine Goals, Objective and Needs

The overall mission of CALFED is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay/Delta system. The CMARP team reviewed numerous CALFED documents to refine specific program objectives that could be used in turn to help define the programs' information needs. Some of the documents included in this review were:

- ERP Volume 1. Ecological Attributes of the San Francisco Bay/Delta system.
- ERP Volume 2. Ecological Management Visions
- Strategic Plan for Ecological Restoration
- Water Quality Program Plan
- Water Use Efficiency Program
- Watershed Program Plan
- Species and Habitat Conservation Plan
- Storage and Conveyance Process Overview
- Developing a Draft Preferred Alternative (11/98).
- CALFED Revised Phase II Report (11/98)

The individual program goals and objectives were provided to the workteams for their consideration in developing proposals for monitoring and research strategies within each program.

Task 2: Develop a Conceptual Framework

Conceptual modeling is the first step in the adaptive management process. As mentioned earlier, adaptive management is an integral component of all CALFED actions. If adaptive management is "learning by doing" (Walters, 1997), conceptual modeling is an explicit summary of what we know before we start doing. Conceptual modeling is an essential tool to help managers and scientists select projects and actions having the greatest likelihood of achieving the desired goals and objectives.

The CMARP Steering Committee sponsored a two-day conceptual modeling workshop (see Appendix ___ for the final report) and encouraged CMARP workteams to include conceptual models in the final reports. At the workshop, representatives from Puget Sound, South Florida, and Chesapeake Bay described their experience with the use of conceptual models in monitoring/research program design.

Several conceptual models are described in Chapter 5 of this document and in many of the technical appendices. From their variety and complexity, it is apparent that conceptual models take many forms and that some models have better scientific support than others. However, the process of conceptual model development has helped participants articulate their understanding regarding the key ecosystem relationships and presumed stressors, and to identify the major issues that need to be addressed and questions that need to be answered. The integration of explicit conceptual modeling in a multitude of existing monitoring/research programs is a significant early accomplishment of the CMARP process.

Task 3: Monitoring Program Design

Monitoring is conducted for many purposes and the terminology used to describe each purpose varies considerably among agencies and programs. For purposes of this report, we use the National Research Council's (1990) terms, with the definitions slightly

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modified for the CALFED program.

1. **Compliance monitoring** provides information needed to determine if activities are meeting permit or other regulatory requirements.
2. **Model verification monitoring** provides information to evaluate management alternatives; e.g., for adaptive management.
3. **Trend monitoring** helps identify long term changes occurring as a result of human and natural factors.

The Council also emphasized that monitoring is an integral component of environmental management and can include modeling, time series measurements, research, and data collection, analysis, interpretation and reporting. For CALFED, the synthesized information can be used to prepare a "report card" to Congress, legislators, public, stakeholders, etc. on progress towards achieving CALFED goals.

Existing monitoring programs already collect a variety of data on physical, chemical, and biological variables such as salinity, temperature, light penetration, flow, pH, chlorophyll, and numbers of many species of organisms. Monitoring under CMARP will incorporate many of the existing activities and will also augment these programs to ensure complete coverage in time and space and add critical variables, as necessary.

The following are elements within the monitoring program development task.

<u>Inventory Existing Monitoring Programs</u>. The inventory of existing monitoring has been particularly important in identifying the scope and content of ongoing programs and exposing the gaps in coverage and content left open because of different objectives of individual programs. The inventory identified 622 monitoring and research programs with a total budget approaching $30 million annually. Almost $28 million is budgeted for the following seven large programs:

- Interagency Ecological Program
- CVPIA Comprehensive Assessment and Monitoring Program
- DWR Municipal Water-Quality Investigations
- SFEI Regional Monitoring Program plus wetlands, watershed, and exotic species
- Sacramento River Watershed Program
- USGS National Water Quality Assessment Program
- USGS Bay/Delta Ecosystem Project

CMARP will also build on results of several research projects funded through Category III and other CALFED programs including:

- Contaminants - distribution, accumulation, and effects
- Introduced species
- Organic carbon - sources and sinks

Develop Specific Monitoring Elements. The CMARP Steering Committee charged the workteams to:

- Review their (and other related) monitoring needs and research,
- Develop conceptual models,
- Recommend monitoring and research needed to respond to CALFED actions, to increase understanding and to provide for long-term trend monitoring.
- List indicators that could be used by CALFED and others to evaluate the success of their actions.

The results of these deliberations are found in the technical appendices and summarized in Chapter V of this report. Most teams identified specific variables to be included in trend monitoring and some general research questions, but were unable to recommend more specific monitoring until the CALFED preferred alternative and Stage 1 actions are better defined. The monitoring and research items have not been ranked by priority, and any cost estimates are very rough. During CMARP early implementation (essentially CY 99, see below), the CMARP Steering Committee and staff will work with CALFED program managers, stakeholders, and agency staff to set priorities and refine cost estimates for the high priority projects. Priorities will depend in part on the preferred alternative and accompanying actions.

Develop a Process for Data Management. CMARP is proposing a relational database-management system that will allow individual data collectors and data providers to manage their own data locally, while providing a means of uploading the data into a larger database. These data will be fully protected by the data management structure; only the data provider will be permitted to change their data. Collected and uploaded data will be subject to a strict QA/QC (quality assurance/quality control) protocol. Data on the comprehensive database can be used for analysis and reporting by agency and stakeholder scientists. Research data may be withheld from general access for a specified period (perhaps two years) to give the researchers time to analyze, interpret results, and publish the information in peer-reviewed journals or other publications.

Develop a Process for Data Assessment and Reporting. Raw data are of little use in making management and policy decisions. A common problem of many monitoring and research programs is the failure to sufficiently analyze collected data and to make the information available to other scientists, managers, stakeholders, and the general public. Often, this failure results from program budgets that do not allocate sufficient staff time for data analysis and interpretation. The CMARP data assessment and analysis element (which may also be a called a decision support system), identifies the means of interpreting and reporting collected information to decision-makers. External peer review will ensure that field and laboratory techniques are appropriate and that interpretations are scientifically defensible. The final CMARP budget will provide adequate staffing to ensure timely data analysis, interpretation, peer review, and reporting.

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Task 4: Design a CALFED Focused Research Program

Monitoring data can describe what happened; research is often needed to help explain why and how it happened. Focused research (also called problem-solving research or targeted research) simply means that the research will be done in areas specifically of interest to CALFED and will be essential in making adaptive management decisions. In a sense, adaptive management is focused research in that the actions are framed as hypotheses and data collected to test the hypotheses.

The CMARP research program will be developed to facilitate the CALFED adaptive-management process and provide answers to critical research questions identified by CMARP teams, CALFED, and stakeholders. CMARP research will be funded through three distinct processes.

- Directed-research-- A specific entity, such as a university researcher, will be asked to submit a proposal for a well-defined project. The proposal will be peer reviewed and if found acceptable, will be funded.
- Request for Proposal-- A general solicitation will be made for proposals in one or more areas of interest to CALFED. The proposals will be peer reviewed and the ones that combine relevance to CALFED with sound science will be recommended for funding.
- Agency scientists--These scientists will continue to be involved in independent research and many of their results will be of interest to CALFED.

Appendix ____ of this report includes a proposed proposal-solicitation process and an example solicitation package. This package and the research questions identified by the work teams will be forwarded to CALFED staff for possible use by the Integration Panel in identifying key research questions and to provide a possible interim request for proposal package

Task 5: Develop an Institutional Structure for CMARP

Because of the uncertainty of CALFED's institutional structure, CMARP provides recommendations on interim and long-term structure/organization.

Interim Organization and Management of CMARP--A CMARP Steering Committee will continue to manage the program until the Record of Decision and a final decision on CALFED structure are available. The Steering Committee will report to the CALFED Management and Policy groups through the CALFED Executive Director. The CMARP Steering Committee will designate a scientist, with appropriate staff support, to direct the program during this interim period. The Program Director and Steering Committee members will coordinate CMARP activities with CALFED program managers and deputy directors. Interim operation of CMARP will cost about $400,000 annually. The CMARP Steering Committee also recommends that CALFED funding be allocated for some early implementation projects in 1999. The proposals and funding requirements

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will be developed in early 1999.

Examples of some of possible early implementation actions under CMARP are:

- Develop a better understanding of three key Delta water-quality constituents - bromides, dissolved solids, and dissolved organic carbon.
- Evaluate "flexible operations" as being discussed by the CALFED Diversion Effects Team. Flexible operations will probably involve an expanded version of IEP's real-time monitoring program, perhaps with statistically valid estimates of the numbers of fish salvaged at the Central Valley Program and State Water Project intakes.
- Maintain and tie-in a common vertical datum and expand it to tie-in tidal and stream gages within the Delta. The common datum would assist in modeling for storage and flood impacts, design of shallow water habitat restoration projects, and subsidence evaluations.
- Establish a teams or teams to develop and implement monitoring and research programs to provide CALFED management with information needed to determine how to evaluate the three proposed Stage 1 fish screens and whether to expand or modify these screens at the end of Stage 1.
- Take an active role in documenting non-indigenous species introductions and determine effects of these introductions. These efforts will be closely coordinated with other programs in the IEP, SFEI, and the Coastal Committee of the Western Regional Panel of the National Aquatic Nuisance Species Task Force.
- Carry out a constant fractional marking program at Central Valley Chinook salmon hatcheries to help evaluate hatchery contribution to spawning escapement and ocean and inland recreational fisheries. These data are essential to understanding the effect of restoration actions on Chinook salmon.

Long-term structure--In the long-term, CMARP must have a structure to ensure that the program is responsive, credible and accountable. It must design and direct the scientific program, collect, manage, and distribute data, analyze and interpret data and report findings, provide for extensive scientific review, and collaborate with CALFED managers on adaptive management. It must find a way to effectively use data from existing programs that are not under the direct control of CMARP. To accomplish this, CMARP should be directed by a Chief Scientist and an Executive Officer supported by appropriate technical staff with all activities subject to structured scientific review. CMARP must be a partnership between agencies, stakeholders, universities, and non-profit and private contractors. The actual field and laboratory technicians, scientists, and computer specialists doing the work cannot be identified until the CALFED and CMARP structures are better defined.

Funding Requirements

Given CMARP's present programmatic level of detail, it is not possible to provide a useful estimate of the amount of funding required. A rough estimate can be obtained by looking at the estimate for the total CALFED program through Stage 1 of about $4.5 billion. The collection and interpretation of research and monitoring data at a level appropriate to support adaptive management will probably represent between 10 to 20 percent of the total cost, or from $450-$900 million over seven years ($65-$135 million/year). Existing programs contribute about $30 million per year, with much of the data already being useful to CALFED and the likelihood that some restructuring of the programs will allow them to better meet CALFED needs.

The above is not intended as a definitive estimate of program costs, but as a forewarning that CMARP will be a significant portion of the CALFED budget.

Chapter II. INTRODUCTION

A. Background

CALFED mission and principles. The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The CALFED Mission Statement is supported by a set of Primary Objectives and Solution Principles.

The primary objectives are:

- Water Quality--Provide good water quality for all beneficial uses
- Ecosystem Quality--Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.
- Water Supply--Reduce the mismatch between Bay-Delta water supplies and the current and projected beneficial uses dependent on the Bay-Delta system.
- Vulnerability of Delta Functions--Reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

The Solution Principles are to:

- reduce conflicts in the system,
- be equitable,
- be affordable,
- be durable,
- be implementable, and
- have no significant redirected impacts.

To fulfill its mission, the CALFED Bay/Delta program is proposing substantial changes to many aspects of the Bay-Delta/Central Valley environmental and water-management system. In addition, many member agencies of CALFED are currently charged with activities and programs directly affecting this system.

Mandate for CMARP. In November, 1997, Secretary of the Interior, Bruce Babbitt, requested that U. S. Geological Survey (USGS) assist him in meeting a Congressional mandate to monitor the success of CALFED restoration efforts. Also during November, the Interagency Ecological Program (IEP) and the San Francisco Estuary Institute (SFEI) proposed to the CALFED Policy Group to develop a monitoring and research program for CALFED. USGS presented its proposal to the Policy Group on December 19, 1997 (USGS, 1997). On that day, the Policy Group directed IEP, SFEI, and USGS to develop a joint proposal to design a Comprehensive Monitoring, Assessment, and Research Program (CMARP) for CALFED.

IEP, SFEI, and USGS formed a steering committee that wrote a proposal (CMARP Stage I report, April 24, 1998), had it reviewed by agencies and stakeholders, and presented it to the Policy Group on May 1, 1998. The Policy Group accepted the proposal, provided $1.8M to finance the effort, and directed that the work be done by the end of January, 1999.

The CMARP Stage I report proposed development of a monitoring, assessment, and research program for CALFED's common programs and related agency programs. It called for creation of an expanded steering committee composed of agency personnel and stakeholders (list of members in Appendix A). It proposed performance of 5 tasks:

1. to clarify goals and objectives of CALFED common programs and related agency monitoring and research programs,
2. to develop a conceptual framework for designing a monitoring and research program,
3. to design a monitoring program,
4. to design a targeted research program, and
5. to recommend organizational ingredients necessary for implementing the program.

B. PURPOSE OF CMARP

Monitoring, assessment, and research are 3 steps in an iterative process to understand and manage a natural resource system (figure 1). Monitoring involves measuring and sampling physical, chemical, and biological attributes of the resources and can include social and economic attributes of associated human activities. Assessment involves developing correlations among monitored data, such as between the abundance of a fish species and a factor like river flow that might affect abundance. Research involves analysis or experiments to establish mechanisms that explain observed correlations, such as documenting fish distributions and mortalities for different flows. The information generated from monitoring, assessment, and research provides resource managers with understanding needed to design actions and to detect responses to their actions.

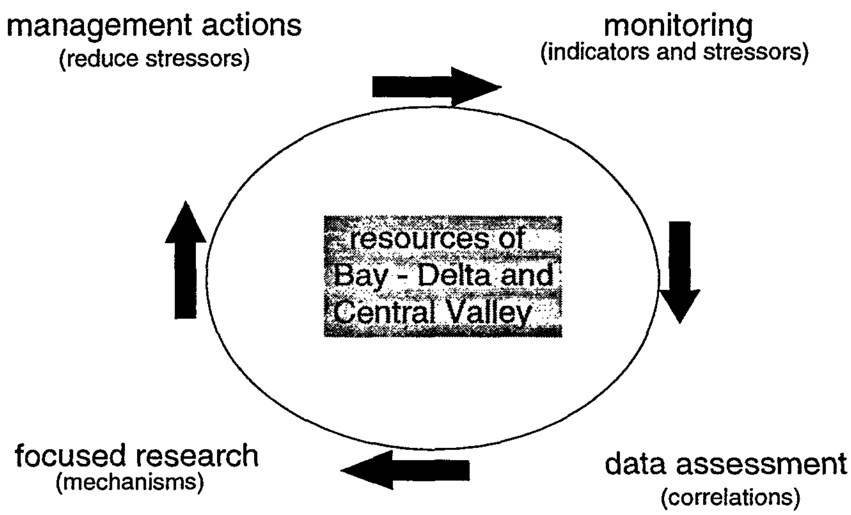

Figure 1 – elements of understanding and managing the natural resources of the Bay-Delta and Central Valley.

CALFED needs a monitoring and research program for at least 3 reasons. First, CALFED needs monitoring data and information to implement the preferred alternative and common programs, and this need is increased by CALFED's adoption of an adaptive management strategy. Second, CALFED needs to satisfy the Congressional mandate for indicators and performance measures with which to judge the success of restoration efforts. Third, CALFED needs data and information with which to assure stakeholders that the actions being taken are having desired results.

Thus, the purpose of CMARP is to provide those new facts and scientific interpretations necessary for CALFED to implement fully its preferred alternative, including the common programs, and for the public and government to evaluate the success of CALFED actions.

C. Purposes of the report

This report describes the initial design of the monitoring, assessment, and research program, and proposes early implementation tasks and additional program refinement prior to a record of decision on CALFED's programmatic environmental impact report. It recommends a data management and reporting process and organizational ingredients necessary to implement the program. It also documents the process by which the program was designed.

In addition, the report is intended to address a number of issues presently important to CALFED and stakeholders. These include:

- **A need for indicators.** In addition to the Congressional mandate to develop indicators of ecosystem health, a need exists to agree on water supply, water quality, and levee reliability indicators, and perhaps to agree on social and economic indicators of associated human activities. These indicators in turn need to be calculated in an unbiased and clearly defined way based on sound monitoring data and provided to the public in a timely fashion.

- **Adaptive management.** Recognizing the level of uncertainty about the resources, CALFED proposes to use an adaptive approach to managing the natural resources. Adaptive management involves designing and executing actions, monitoring and assessing the responses of the natural resources to these actions, and thereby learning how actions affect the resources. At issue is the nature of adaptive management to be employed, traditional passive adaptive management or a more active adaptive management recommended by the ERP Strategic Plan (, 1998). Another concern is the need for appropriate and timely assessment of monitoring data to make adaptive management effective.

- **Questions raised by DEFT.** Information and assumptions about the effects of delta exports and diversions on the abundance of fish species, particularly threatened species, are the foundation of biological opinions that constrain operation of the Central Valley and State Water Projects to deliver water south of the delta. The Diversion Effects on Fish Team (DEFT) has assessed available information to recommend how to use flexible operations of the water projects to improve the welfare of salmon, delta smelt, and striped bass in the delta. DEFT recognized needs for improved information to help refine and judge the efficacy of its recommendations during Stage I of CALFED program implementation.

- **Drinking water quality of exports and diversions.** As drinking water regulations for disinfection by-products are revised and water treatment technology evolves, and as more blending and recycling of delta water are needed to meet increasing municipal water demands, an increasing need exists to reduce concentrations of bromides, organic carbon, and dissolved salts in delta exports and diversions. CALFED has recognized the need to investigate and implement measures to effect these reductions during Stage I, and these activities will need strong monitoring and research support.

- **Implementing CMARP.** An underlying issue for CALFED and CMARP is what organization or organizations will implement the programs. This issue is particularly important because of the expressed intent to use an adaptive management approach to implement the program. As the debate continues, necessary ingredients for an organizational structure need to be defined.

D. Reader's guide to the report.

Chapter 3 defines the programmatic and geographical scope of CMARP, and the approach used to design the program. Chapter 4 describes the development and use of conceptual models for CMARP and reviews prior efforts to develop indicators. Chapter 5 presents brief sketches of the recommended monitoring and research programs and proposed indicators for all of the CALFED common programs, including DEFT-related work in the ecosystem restoration section and drinking water-related work in the water quality section. More detailed descriptions of the design work are presented in the numerous appendices to this document. Chapter 6 discusses efforts to develop a data assessment and reporting process to provide information derived from the monitoring data to decision makers, resource managers, and the public. Chapter 7 discusses the consensus reached on organizational ingredients needed to implement CMARP. Chapter 8 contains recommendations for early implementation tasks (including DEFT- and drinking water-related tasks) and program refinements during 1999, clarifies the issue of active adaptive management, and discusses costs and financing for CMARP.

Chapter III. SCOPE OF CMARP AND APPROACH TO DESIGN

A. SCOPE OF THE CMARP

Organization
The CMARP organizational structure (Figure _) was developed to maximize the flow of information and interaction between the Steering Committee, agency staff, stakeholder groups and program managers for the CALFED common programs. Some 30 technical work teams (Appendix __) developed technical recommendations for research and monitoring, the basis of which were the CALFED common programs and tasks to be completed by the CMARP. About 250 individuals represented stakeholder groups, agency staff, CALFED staff, CALFED program managers, and other area scientists on these work teams. Representatives of major monitoring programs (Sacramento River Watershed Program, San Francisco Estuary Institute, DWR's Municipal Water Quality Investigations Unit, Interagency Ecological Program and similar organizations) ensured that the CMARP take advantage of existing monitoring programs and incorporate specific agency and stakeholder needs.

Twelve large, ecosystem-level management projects across the United States were reviewed to gather information, examples, and advice to use in the creation and refinement of the CMARP design. The Steering Committee contracted with the Green Mountain Institute for
Environmental Democracy (GMI) to work together with members of U.S. Geological Survey and the San Francisco Estuary Institute (SFEI) to gather details of the institutional structures, the decision-making process, monitoring and research programs, feedback loops, and advice from these programs. This information was gathered through interviews with key individuals in each system and collecting documents from the various programs. The projects reviewed were Chesapeake Bay, South Florida/Everglades, Puget Sound, the Southern Appalachian Assessment, the Mid-Atlantic Integrated Assessment, the Interior Columbia Basin
Ecosystem Management Project, Great Lakes, Gulf of Mexico, Prince William Sound, Gulf of Maine, the Forest Ecosystem Assessment, and the Greater Yellowstone Ecosystem. Additionally the regional monitoring program of the Southern California Coastal Waters Project was reviewed. The Green Mountain Institute is currently digesting the massive amount of information that was compiled and distilling it into a summary of the key findings and a longer narrative. This report will be available as an appendix to the CMARP report soon. The information from the interviews has already been used to improve the recommendations of the Institutional Structure and Data Management, Assessment and Reporting Chapters and Appendices. The supporting documents acquired in the evaluation process will be compiled into a library of materials to serve as a reference tool to CMARP and CALFED.

Geography
The geographic scope of the CMARP is determined by attributes of the chemical, biological and physical environment associated with implementation of CALFED Stage 1 actions. For example, monitoring chinook salmon necessitates some form of

sampling from the headwaters, down the rivers, through the Bay/Delta and into the ocean. Conceptual models of the life histories of salmon were used to determine the specific variables that will be monitored and to identify when and where monitoring should occur. Monitoring associated with other program elements, such as water transfers, will also have wide geographic scope.

<u>Types of Monitoring--Principal CMARP monitoring objectives include</u>

- documenting conditions;
- recognizing trends;
- assessing causes of observed changes;
- partnering with agency/ecosystem management for adaptive management; and
- reducing scientific uncertainties.

CALFED will need to assure the regulatory community and stakeholders that certain actions specific to project development are being done. Examples include implementing mitigation measures that address project effects and complying with standards and objectives required as permit conditions to construct and operate projects. Different types of monitoring will be implemented to address these objectives. None are mutually exclusive and some are interdependent. They do not necessarily require distinct and independent data collection efforts. The objectives and plans of each monitoring program will be clearly specified. In the process, the overlaps in data needs between programs will be identified and eliminated, thereby achieving considerable cost savings.

- Baseline Monitoring--Indicates current conditions relative to a selected time-period. It requires monitoring of variables that show long-term trends that are not masked by daily or seasonal variations. It addresses the question "*what has changed*?"
- Trend Monitoring—Monitors long-term changes in key indicators or conditions (includes variables fish populations, streamflow, temperature, and salinity) that are most likely associated with changes in key conditions. It addresses the questions "*when*" and to some extent, "*why*" things have changed.
- Effectiveness Monitoring--Determines whether and to what degree any specified practice achieved its immediate objectives. (Did the project do what it was supposed to do)? Effectiveness monitoring validates hypotheses and conceptual models that predict relationships among variables. It validates theories on the effectiveness of certain actions.
- Compliance/Mitigation Monitoring--Determines whether and to what degree specified objectives, standards or mitigation measures are being met. A permitting authority usually requires this type of monitoring as a result of project development and operation.
- Operations Monitoring--Supports specified project operations. It is intended to provide up-to-date (within 24 to 48 hours) information to management and operators on effects of project operations for specified environmental variables, or provide specified environmental information to determine how projects should operate. This monitoring is a tool that allows for flexibility in

project operations. Examples include real-time fishery and water-quality monitoring.

Inventory of Monitoring and Research Programs

One of the cornerstones of the CMARP recommendations is the construction of the monitoring and research program around existing programs. Numerous monitoring programs currently exist in the CALFED region, each implemented for different reasons. Therefore, it is not surprising that each approach sampling, analysis, and reporting approaches. A key goal of CMARP is to cooperatively use the information that each program produces, together with new efforts, to provide comprehensive information for management.

The purpose of the inventory was to document information about existing monitoring programs and create a world wide web site where anyone wanting to find out who is monitoring what, could do so. The inventory may be accessed on the world wide web at: www.sfei.org/cmarpinv. It can also be accessed via CMARP and IEP www sites. When completed, the inventory will reside on the CALFED server and be linked with CERES.

The www site uses database-search procedures to list information about each existing monitoring program. Interested persons may search by CALFED Common Program and by general geographic area. More sophisticated search capabilities are being designed. Sampling-site maps are included for programs if they were made available.

The inventory included information from several existing inventories:

- UC Davis' Information Center for the Environment (ICE).
- Watershed Programs Inventory
- Ecosystem Restoration Programs Inventory
- Noxious Weeds Survey
- SFEI's inventory of water quality monitoring programs in the Bay-Delta, recently completed for the State Water Quality Control Board.
- DWR's Compendium of Water Quality Investigations. (not yet linked to the inventory).

The CMARP Inventory has linked those inventories, and has added many other programs. More are being added daily. As of November 1998, we have identified 622 monitoring and research programs. Those programs include a wide range of Federal, State, municipal, local, and volunteer programs that encompass most of the CALFED program areas. Over 185 ecosystem restoration programs have been identified in the Sacramento River Watershed (Table 1). Over 125 Water-Quality monitoring programs were identified in San Francisco Bay. Several Levee-monitoring programs have been identified, but the program information has not yet been included in the Inventory. Some Water-Transfer-monitoring information on ground- and surface-water levels is categorized under Watershed Management.

Examples of www site information for nine of the largest programs are listed in Appendix X and summarized on Table 2. Almost $27 million is currently spent annually on monitoring and research in the CALFED regions by those programs. That figure certainly underestimates the total of all programs, and does not include Category III costs.

More information is expected as additional request forms are returned. The search function on the web page is being improved to allow searching by a number of keywords. The Inventory is expected to be completed by mid-December 1998.

Table III-1. Existing monitoring programs* compiled in the Inventory, sorted by CALFED Common Program and geographic region.

	Ecosystem Restoration	Delta Levees	Watershed Management	Water Quality	Water Transfers and Use Efficiency**	
San Joaquin River	76	0	37	21	0	134
Sacramento River	184	0	12	39	0	235
Bay	15	0	1	128	0	144
Delta	53	0	3	51	2	109
Totals	328	0	53	239	2	622

*Several levee monitoring programs and sources of water transfer monitoring information have been identified but are not yet included in the inventory. More information will be entered into the inventory as additional program survey forms are returned.

** Some water transfer monitoring information on ground- and surface-water levels is categorized under "Watershed Management"

Table III-2. Summary of information about the largest existing monitoring and research programs in the CALFED Region. Costs are annual estimates.

Organization	**Areas**	**Time Frame**	**Monitoring**	**Applied Research**	**Other**	**Total**
San Francisco Estuary Institute (SFEI)	Bay Region	1993 - present	$2.5 M	$1.5 M	$0.4 M	$4.4 M
Interagency Ecological Program (IEP)	Bay and Delta Region	1996 - present	$4.9 M	$6.3 M	$1.5 M	$12.7 M
Comprehensive Assessment and Monitoring Program (CAMP)	Sacramento and San Joaquin River Regions	1997 - present (1952 earliest subprogram begun)	$2.4 M	$0	$132,000	$2.5 M
Sacramento River Watershed Program (SRWP)	Sacramento River Region	1996 - present	$0.5 M	$0	$0.5 M	$1 M
Municipal Water Quality Investigations Program (MWQIP)	Delta Region	1982 - present	$0.4 M	$1.2 M	$0.3 M	$1.9 M
Sacramento Coordinated Monitoring Program (SacCMP)	Sacramento and San Joaquin River Regions	1992 - present	not reported	not reported	not reported	not reported
USGS San Francisco Bay and Delta Ecosystem Program	San Francisco Bay and Delta Regions	1995	$0	$1+ M	$0	$1+ M
USGS National Water Quality Assessment Program	Sacramento and San Joaquin River Regions	1991 - present	$2.2 M	$0	$0	$2.2 M
Grasslands Bypass Program	San Joaquin River Basin	1996 - present	$0.75 M	$0.5 M	$0	$0
Total	---	---	$13.65 M	$10.5 M	$2.8 M	$26.95

Appendix X. Examples of information available in the CMARP Inventory of Existing Monitoring Programs. The entire inventory is accessible through the world wide web at: www.sfei.org/cmarpinv.

Program: **Interagency Ecological Program (IEP)**

Contact: Chuck Armor, Department of Fish and Game, Bay Delta Division
4001 North Wilson Way, Stockton, CA 95205
(209) 948-7800, (209) 946-6355 fax
carmor@delta.dfg.ca.gov

Program Objectives:

- To provide for the collection and analysis of data needed to understand factors in the Sacramento-San Joaquin estuary controlling the distribution and abundance of selected fish and wildlife resources and make the data readily available to other agencies and the public.
- To comply with permit terms requiring ecological monitoring in the estuary.
- To identify impacts of human activities on the fish and wildlife resources.
- To interpret information produced by the program and from other sources and, to the extent possible, recommend measures to avoid and/or offset adverse impacts of water project operation and other human activities on these resources. To seek consensus for such recommendations, but to report differing recommendations when consensus is not achieved.
- To provide an organizational structure and program resources to assist in planning, coordination, and integration of estuarine studies by other units of cooperating agencies or by other agencies.

Start Date: IEP formed in 1972. Inception date of individual programs vary.

Attributes Measured: Hydrodynamics; Water quality;
Lower trophic organisms (e.g., zooplankton, phytoplankton); Fish & macroinvertebrates

General Area: Between and including San Pablo Bay and the Delta

Number of Sampling Sites: Numerous

Frequency: Hydrodynamics: continuous
Water quality: both continuous and discrete monthly measurements.
Lower trophic organisms: both continuous chlorophyll sampling and monthly zooplankton sampling.
Fish and macroinvertebrates: varies between bimonthly sampling and periodic collection.

Budget: Monitoring: $4.9 million
Special Studies: $6.3 million
Program Management $1.5 million

Program: **Comprehensive Assessment and Monitoring Program (CAMP)**

Contact: Larry Puckett, U.S. Fish and Wildlife Service
3310 El Camino Avenue, Sacramento, CA 95821
(916) 979-2760, (916) 979-2770 *fax*
larrypuckett@fws.gov

Program Objectives:

- To assess the overall (cumulative) effectiveness of actions implemented pursuant to CVPIA Section 3406(b) in meeting AFRP production targets and
- To assess the relative effectiveness of categories of Section 3406(b) actions (e.g., water management modifications, structural modifications, habitat restoration, and fish screens) toward meeting AFRP production targets.

Start Date: CAMP was developed in 1997. Inception date of individual programs vary (earliest began in 1952).

Attributes Measured: Varies according to program. Juvenile and adult surveys of Chinook salmon, steelhead trout, striped bass, white sturgeon, green sturgeon and American shad. Monitoring includes: population estimates, spatial and temporal spawning distribution, length frequency, sex ratio, fish mark/recapture, water clarity and water temperature. Ladder counts, snorkel surveys and carcass surveys.

General Area: Central valley watersheds

Number of Sampling Sites: Numerous

Frequency: Varies according to program from daily (continuous) to annually

Budget: $2.5 million

The $2.5 million budget shown for CAMP reflects the amount spent on field monitoring, either for new monitoring programs or to subsidize existing programs. The total budget, which now stands at about $5 million, includes what the individual agencies pay and can fluctuate greatly from year to year with the start or finish of short-term monitoring projects.

Program: Department of Water Resources, **Municipal Water Quality Investigations Program**

Contact: Rich Breuer, 1020 9th Street, 3rd Floor
Sacramento, CA 95814

Phone: (916) 327-1726, (916) 227-1648 Fax
Rich@water.ca.gov

Program Objectives:

- To determine and evaluate the source of contaminants that affect the drinking water quality of the Sacramento — San Joaquin Delta
- Alert water agencies about current and potential contaminants in Delta water supplies
- Assist water supply agencies in planning, protecting, and improving drinking water sources and water supply facilities
- Document water quality under a variety of hydrologic conditions for studying: water transfer alternatives, water quality standards and predictive modeling capabilities

Start Date: 1983

Attributes Measured: Varies by site; includes: Standard mineral, turbidity, UVA, TOG, DOG, Bromide, DWR-modified THMFP, reactivity-based THMFP and 1-JAAFP, Ammonia, MTBE.

General Area: Delta

Number of Sampling Sites: 13 (varies yearly)

Frequency: Varies between weekly and monthly measurements

Budget: Monitoring: $350,000
Applied Research: $1,175,000
Other: $325,000 (Program Management)

Program: **San Francisco Estuary Institute (SFEI), Regional Monitoring Program**

Contact: Margaret Johnston, San Francisco Estuary Institute
1325 South 46th Street, Bldg. 180, Richmond, CA 94804
Phone: (510) 231-9539 x532; (510) 231-9414 *fax*
johnston@sfei.org

Program Objectives:

- To obtain baseline data describing the concentration of toxic and potentially toxic trace elements and organic contaminants in the water and sediment of the Estuary;
- To determine seasonal and annual trends in water quality in the Estuary;
- To continue to develop a data set that can be used to determine long-term trends in the concentrations of toxic and potentially toxic trace elements and organic contaminants in the Estuary;
- To determine whether water quality and sediment quality in the Estuary are in compliance with objectives established by the Regional Board's Basin Plan;
- To provide a database on water and sediment quality in the Estuary which is compatible with data being developed in other ongoing studies in the region.

Start Date: 1993

Attributes Measured:

- Water Quality (salinity, temperature, dissolved oxygen, suspended sediment, etc.)
- Water Contamination (trace elements and organics, dissolved and particulate fractions)
- Aquatic Bioassays (using mysids and larval bivalves)
- Sediment Quality (grain size, organic material, ammonia, sulfide)
- Sediment Contamination (trace elements and organics)
- Sediment Bioassays (using amphipods and larval bivalves)
- Transplanted Bivalve Bioaccumulation (trace elements and organics)
- Transplanted Bivalve Survival and Condition

General Area: San Francisco Bay

Number of Sampling Sites: 24

Frequency: Water quality: wet season (usually February), declining flows (usually April), dry season (usually August)
Sediment and bivalve bioaccumulation: wet and dry seasons

Budget: RMP: $2.5 million for 1997
Other: $1.5 million (for wetlands & watersheds program, biological invasions)

Program: **Sacramento River Watershed Program**
Contact: Tom Grovhoug, Larry Walker Associates
509 Fourth Street, Davis, CA 95616
(916) 753-6400 (916) 753-7030 *fax*
lwa@davis.com

Program Objectives:

- To ensure that current and potential uses of the watershed's resources are sustained, restored and, where possible, enhanced while promoting the long-term social and economic vitality of the region.
- In coordination with other subcommittees and the larger stakeholder group, develop a cost-efficient and well-coordinated long term monitoring program within the watershed to identif5r the causes, effects and extent of constituents of concem that affect the beneficial uses of water and to measure progress as control strategies are implemented.
- To assess conditions in the main stem of the Sacramento River through the collection of baseline information, with an emphasis on examining the degree to which beneficial uses are attained or potentially impaired.

Stan Date: Spring 1998 (some elements began in 1997)

Attributes Measured:

- Mercury, PCB's and chlorinated pesticides in fish tissue
- Trace metals in water (arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium, sliver and zinc)
- Aquatic life toxicity in water and sediment
- Pathogens in water *(Cryptosporidium, Giardia,* coliforms)
- Organic carbon in water
- General constituents (minerals, nutrients, solids, turbidity, hardness) in water
- Benthic invertebrates
- Algae (attached and planktonic)

General Area: Sacramento River watershed from above Shasta dam to near Rio Vista in the Delta, including several major tributaries.
Number of Sampling Sites: 63 total sites; number varies according to attribute.
Frequency: Basic chemical characteristics: varies between monthly and semi-monthly
Pathogens: varies between monthly and quarterly
Chronic aquatic toxicity in water: varies between monthly and semi-monthly
Sediment toxicity: twice annually
Fish tissue analysis: once annually
Budget: Monitoring: $500,000 for the first year.
Other: $500,000

Program: **Sacramento Coordinated Monitoring Program**
Contact: Tom Grovhoug, Larry Walker Associates
509 4th St., Davis, CA, 95616
530 753 6400
tomg@lwadavis.com

Program Objectives: Coordinate monitoring activities to produce a scientifically defensible database of water quality information on the Sacramento and American Rivers in the Sacramento metropolitan area.
Start Date: 1992
Attributes Measured: Total and fecal coliforms, dissolved organic carbon, temperature, dissolved oxygen, hardness, total suspended solids, and electrical conductivity.
General Area: Sacramento River watershed
Number of Sampling Sites: 5
Frequency: monthly and storm events
Budget: not reported
(research/monitoring/other)

Program: Bureau of Reclamation
Grasslands Bypass Project Toxicity Program
Contact: Mike Delamore
Bureau of Reclamation
2666 North Grove Industrial Dr.
Fresno 93727
(209) 582-9237
mdelamore@mp.usbr.gov
Program Objectives: To remove selenium contaminated subsurface agricultural drainage water from wetland channels.
Start Date: 1996
Attributes Measured: Flow, temperature, specific conductance, selenium, pH, TSS, boron, toxicity (growth, reproduction, survival).
General Area: San Joaquin River Basin
Number of Sampling Sites: 13
Frequency: Daily, weekly, monthly, quarterly
Budget: $750,000 monitoring, $500,000 applied research.

Program: U.S. Geological Survey, **National Water Quality Assessment Program**
(Sacramento and San Joaquin Basins)
Contact: Joe Domagalski (Sacramento), Charlie Kratzer (San Joaquin)
U.S. Geological Survey, Placer Hall, 6000 J St.
Sacramento CA 95815 - 6129
916 278 3077 (Sac), 3076 (S.J.)
joed@usgs.gov, ckratzer@usgs.gov
Program Objectives: To determine the status and trends of water quality in rivers, lakes and streams as influenced by human activities, and evaluate sources of water quality problems.
Start Date: 1991 (San Joaquin) 1993 (Sacramento)
Attributes Measured: *San Joaquin.* Nutrients, major ions, 94 pesticides, selenium, boron, molybdenum, dissolved oxygen, pH, continuous flow and temperature in surface water, similar attributes in groundwater. Number and species of fish, clam tissue analysis, sediment organics, algae benthic assessment.
Sacramento. Nutrients, pH, conductivity, dissolved oxygen, pesticides, VOCs in water; major ions, trace elements, and hydrophobic compounds in sediment.
General Area: Sacramento and San Joaquin River watersheds
Number of Sampling Sites: 10 to 50 depending on attribute measured (San Joaquin), 12 (Sacramento)
Frequency: Monthly, storm events, and 1 to 3x per week at some sites, depending on attribute (San Joaquin). Monthly (Sacramento)
Budget: $1.9 Million (Sacramento) $1.3 Million (San Joaquin), $2.2 Million total.

Program: U.S. Geological Survey, **San Francisco Bay and Delta Ecosystem Program**
Contact: Fred Nichols, U.S. Geological Survey
345 Middlefield Road , Menlo Park, CA 94025, USA
(650) 853-8300, fnichols@usgs.gov
Program Objectives: To augment hydrological, biological, and geological investigations in the estuary and delta to develop technical information relevant to problems faced by State and Federal resource managers, and to develop a system to provide this information to interested parties.
Start Date: 1995
Attributes Measured: Organic pesticides, flows, sediment transport, contaminant, effects of metals on reproduction and health of clams.
General Area: San Francisco Bay and Delta
Number of Sampling Sites: varies by research project
Frequency: variable by research project
Budget: $1+ Million

B. Approach to Design

Principles

Prior to developing the monitoring and research recommendations, members of the Steering Committee, agency staff and CALFED staff agreed to several principles, which formed the basis for the principal CMARP work tasks and provided the direction necessary for completing the work products. The principles are:

- Recommendations for monitoring and research are based upon development of conceptual models that incorporate current thinking about how the ecosystem is structured and how it functions.
- CMARP is to be built upon existing monitoring programs, where feasible, resulting in reduced capital and operation costs.
- To maintain objectivity in reporting monitoring and research information, CMARP is to operate independently of funding sources while providing accountability to a governing body.
- Emphasis of a CMARP will be on data evaluation and use. Evaluative reports, subject to peer review, will be published on a regular basis.
- CMARP is to be fully coordinated with similar assessment activities of other local, State, Federal and regional organizations. Duplication of effort will be minimized.
- Through a quality assurance and control program, CMARP will encourage the standardization of sampling equipment, sampling methodologies and analytical methodologies.
- CMARP's data management structure will ensure that data collected are available to public agencies and the public on a timely basis.

Development of Recommendations
Five main work tasks were established by the Steering Committee (Table __).

Table __
CMARP STEERING COMMITTEE TASKS

- **TASK NUMBER ONE – Refine the Goals, Objectives and Needs of CALFED Common Programs, Related Programs, and Agency Major Program Goals and Objectives**
  A continuing and iterative process to:

  A. Identify goals, objective, and needs of CALFED Common Programs (Ecosystem Restoration, Water Quality, Water Transfers, Water Use Efficiency, Watershed Management and Delta Levees) and related programs (Category III, Conservation Strategy and Indicators).
  B. Compile Agency major program goals and objectives.
  C. Develop CMARP monitoring elements and a research program based on
  D. identified goals and objectives.

- **TASK NUMBER TWO – Develop a Conceptual Framework**
  Focuses the development of explicit conceptual models for use in designing monitoring and research programs. Also useful for documenting the basis of earlier decisions on program design. This task is being accomplished, in part, by taking advantage of experience gained in the development of monitoring and research programs in Puget Sound, Chesapeake Bay and South Florida.

- **TASK NUMBER THREE – Monitoring Program Design**
  Comprised of five sub-tasks:
  A. Inventory Existing Monitoring Programs
  B. Develop Monitoring Elements
  C. (See Organization chart for 6 elements and 13 sub-elements).
  D. Develop a Process for Data Management
  E. Develop a Process for Data Analysis and Monitoring
  F. Category III Monitoring Institutional Process

- **TASK NUMBER FOUR – Design a CALFED Focused Research Program**
  Investigate causes of ecosystem variability, change, and long-term trends.

- **TASK NUMBER FIVE – Recommend an Institutional Structure for Monitoring, Assessment and Research**
  Identify functions of a CMARP institutional structure and its relationship to CALFED. recommend how it should operate; how it should be funded; and to whom it should be accountable.

Initial activities to develop monitoring and research recommendations began with a review of the established CALFED goals and objectives for all six common programs, including the Conservation Strategy and Category III elements. Work with agency staff and stakeholders to identify CALFED agency goals and objectives for existing monitoring and research programs was also done. However, the short timeframe for development of a product required simultaneous progress on most elements with the work teams achieving consensus on addressing what needs to be monitored; why it needs to be monitored; and more specifically, when and where it should be monitored. The details on how a particular element should be monitored (e.g., gear type/methodology) and who will do the monitoring were postponed pending approval to work on implementation of CMARP elements.

D-049548

CHAPTER IV. CONCEPTUAL MODELS AND INDICATORS

A. USES OF CONCEPTUAL MODELS IN MONITORING AND RESEARCH DESIGN

INTRODUCTION

The term "conceptual model," in the context of environmental monitoring, has been generally defined as a "description of causes and effects that define how environmental changes are expected to occur" (National Research Council, 1990). The intention of conceptual modeling is to show how processes may be linked across space, time and trophic levels (cause-effect relations), to help formulate specific testable questions to be answered through monitoring and research, and to lead to predictions about the effects of environmental perturbations or management actions. In their simplest form, conceptual models can be used to describe complex system processes to policy makers and to the public. Despite the importance of conceptual models in environmental management, however, they do not represent finished products. Rather, it is the process of thinking about, developing, and revising conceptual models that provides the greatest benefit to the users. As described in the "Strategic Plan for [the CALFED] Ecosystem Restoration Program (1998),

> "Conceptual models are based on concepts that can and should change as monitoring, research, and adaptive probing provide new knowledge about the ecosystem. When key concepts change, the conceptual models should be updated to reflect these changes, thereby paving the way toward changes in management."

Despite the importance of conceptual models in environmental management, existing explicit models of the features of the San Francisco Bay-Delta and its watershed are limited to a few species and system functions. Bay, Delta and watershed scientists, engineers, and resource managers may have well developed ideas about how particular features of the system function and may be influenced by natural and human-induced stressors, but these ideas are seldom formalized into a format that can be shared with, and discussed by others. With the recognition that conceptual models should be the centerpiece of the design of both monitoring and research programs directed toward CALFED needs, the development of explicit models of major features of the estuary and its watershed is a major thrust of the Comprehensive Monitoring, Assessment, and Research Program (CMARP).

DEVELOPMENT OF CONCEPTUAL MODELS IN CMARP

In June 1998, CALFED and agency staff, university researchers, stakeholders, and representatives of restoration and monitoring programs from outside California participated in a workshop to discuss the role of conceptual modeling in developing CMARP research and monitoring programs (see the notes from the workshop in Appendix _). The participants of the workshop, drawing on experience gained in programs in Puget Sound, Chesapeake Bay, and South Florida, concluded that conceptual models must play an important role in the design of CAFED programs. However, workshop participants agreed that existing models are mostly implicit, i.e., not well documented, and are not generally available. Moreover, it was agreed that CALFED and local, state and federal agencies are presently not making good use of conceptual models in developing monitoring/restoration programs, in adaptive management, or in communications with other scientists, managers, and the public.

Subsequent to the June workshop, the CMARP workteams have incorporated conceptual modeling as an integral part of the monitoring and research design process. Using existing knowledge and theories, the workteams have identified and described the key features or attributes of the system under study, the inter-relations among them, and the important environmental factors (including stressors) that influence them. These models take a variety of forms, from descriptive texts to complex diagrams and combinations thereof. Whatever the format or complexity, the intent of these models is to provide the authors' written descriptions of the specific habitat, species, or system attributes and functions and the forces acting upon them. In many instances there is not unanimity of opinion about the described features and linkages. However, the point of preparing and presenting these conceptual models is to BEGIN the discussion of the attributes, functions, and linkages described by the models, to undertake the formulation of specific questions and hypotheses, to develop appropriate monitoring and research strategies, and to provide a scientific basis for adaptive management.

MONITORING PROGRAM DESIGN

Conceptual models of individual species (e.g., winter run salmon), habitat types (e.g., shallow water), physical processes (e.g., hydrodynamics), or ecosystem functions (e.g., primary productivity) lead naturally to the development of working hypotheses about important linkages and how the system will respond to management interventions. These hypotheses, in turn, suggest the lists of variables that will need to be measured to document the status and trends of system properties, and more generalized system indicators that can provide the basis for assessing progress in meeting CALFED's objectives.

A critical role of conceptual modeling is to narrow the list of the many possible monitoring variables to those that, within appropriate space and time scales, will produce the specific information required, i.e., that are focused on the system attributes that are of greatest concern. Some of these variables can also serve as the broader indicators or attributes that are expected to change over time in response to restoration actions. A primary purpose of the CALFED monitoring program will be to measure the status of those indicators, e.g., collecting and reporting on basic information about the critical species, habitats, and system functions and any changes that occur as a result of management actions.

For many attributes of the San Francisco Bay-Delta and watershed system, monitoring programs are already in place that can be used in the formulation and testing of hypotheses. The conceptual models assist in uncovering the gaps in these programs such as the need for more complete spatial or temporal coverage, the need for better coordination, the need for improved standardization, the need for additional variables, or the need for new or more sophisticated interpretation of existing data.

RESEARCH PROGRAM DESIGN

Conceptual models are extremely useful in identifying gaps in our understanding of critical system processes and interactions. Addressing these gaps will require targeted research investigations that can include testing of hypotheses, distinguishing among alternative hypotheses, addressing critical unanswered questions, and quantifying interactions, e.g., through combinations of field and laboratory experimentation and/or quantitative numerical modeling.

Primary goals of the CALFED Focused Research Program are to:

- build upon our existing understanding of physical, chemical, and biological processes in those areas that are relevant to CALFED program actions;
- provide information useful in evaluating the effectiveness of existing monitoring protocols and the appropriateness of monitoring attributes;
- test causal relationships among environmental variables identified in conceptual models;
- reduce areas of scientific uncertainty regarding management actions;
- incorporate relevant new information from non-CALFED-sponsored research; and
- revise conceptual and numerical models as our understanding increases.

To achieve these goals, the CALFED research program will establish clear priorities for research and incorporate peer review of proposals, ongoing work, and finished products.

The conceptual models developed to date suggest a variety of research questions that are very relevant to the fundamental questions being addressed by CALFED and that are critical to the design of "adaptive probing to about the best management solutions (Strategic Plan for ERP, 1998)." The major CMARP task during the next six months will be to synthesize and prioritize among the many research ideas and to develop a strategy for undertaking the most critical of these targeted research efforts. The strategy will involve two mechanisms for supporting CALFED-targeted research:

1. an annual request-for-proposals process in which the scientific community at large will be asked to submit research ideas that address specific CALFED research needs; and
2. the establishment of a directed research effort, overseen by a CALFED Science Review Board, that undertakes a sustained, coordinated, interdisciplinary program of study and experimentation on specific problems.

The CMARP Steering Committee, through its technical workteams, is compiling a list of relevant research questions in each of the common program areas. This list will serve as the basis for issuing a series of Proposal Solicitation Packages (PSPs) for research directed toward answering the questions, and for implementing a longer-term, directed research program. Details about the conduct of the CALFED Research Program are found in the Appendices.

ADAPTIVE MANAGEMENT

Conceptual models provide a means for "link[ing] human activities or management actions to outcomes important to society (Strategic Plan for ERP, 1998)." As described by Walters (1997),

> "Adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. This modeling step is intended to serve three functions: (1) problem clarification and enhanced communication among scientists, managers, and other stakeholders; (2) policy screening to eliminate options that are most likely incapable of doing much good, because of inadequate scale or type of impact; and (3) identification of key knowledge gaps that make model predictions suspect."

It is the task of the modeling effort to describe the relationships that potentially link management actions, through ecological processes, to consequences or outcomes for species or ecosystems.

> "[The conceptual] models provide the basis for informed management actions from which a better understanding of the ecological system can be derived. The knowledge and hypotheses about ecosystem responses summarized in conceptual models lead directly to potential restoration actions, although each model is likely to suggest many possible courses of action. ... Such models, and simulation models developed from them, are essential for conveying why certain management actions are expected to produce desirable effects. Alternative, competing conceptual models can illustrate areas of uncertainty, paving the way for suitably-scaled experimental manipulations designed to both restore the system (according to more widely accepted models) and explore it (to test the models)." (Strategic Plan for ERP, 1998)

The models being developed (see Appendices) will be used to examine alternative hypotheses about how the bay-Delta-watershed systems work to identify and clarify both those situations in which uncertainties may influence our decisions about taking specific management actions and those situations in which consensus understanding suggests where management actions are warranted.

B. STATUS OF INDICATOR DEVELOPMENT BY CMARP

Indicators are carefully selected system attributes or indices that define the ecological characteristics, status, and integrity of a system. They are intended to provide a useful, readily understandable means of making an ongoing, scientifically valid assessment of ecological integrity and are designed to lend themselves to evaluation and refinement in an adaptive management process. Two essential qualities of indicators are ecological relevancy and scientific defensibility. Properly selected indicators can:

- Build public support for environmental protection and restoration,

- Track trends in ecological integrity, and
- Provide accountability of long-term efforts to meet program goals.

Several efforts are currently underway to develop indicators to be used in the various portions of the CALFED programs. Through program coordination, the selected indicators share a common organizational structure. Indicators are framed in six categories of ecologically essential attributes or characteristics of the Bay-Delta ecosystem:

- hydrology,
- geomorphology,
- habitat quality,
- native biota,
- energy and nutrient flows, and
- disturbance.

The indicators chosen for each of these categories will vary depending upon the spatial and/or temporal scale being addressed and the program objective being evaluated. The indicators are generally a composite of many measurable variables. In some cases, while a tentative indicator has been identified, work remains in determining the specific variables that make up the components of the indicator.

The Environmental Defense Fund (EDF) is developing Essential Ecological Indicators at the most general scales. The draft EDF document is currently undergoing agency review. The discussion of each indicator described in this document includes general text describing the potential component variables.

Indicators at the next lower level of scale, i.e., at the landscape scale and smaller geographic areas (upper tributaries, alluvial rivers, Delta, and the Bay) were developed specifically for the Ecological Restoration Program.

Indicator development at the habitat and species level by the technical work teams that developed various portions of the CALFED Comprehensive Monitoring, Assessment, and Research Program, has been limited.

As the Comprehensive Monitoring, Assessment and Research Program is developed, the indicators developed to date will be further refined by the teams assembled to design the subunits of the CMARP.

Chapter V. Monitoring and Focused Research Program Design

Part A, Introduction and Reader's Guide

The monitoring plan was developed based on the information needs of the eight CALFED programs (*Ecosystem Restoration, Water Quality, Delta Levees, Storage, Conveyance, Water Transfers, Water Use Efficiency, and Watershed Management) and supporting programs (Category III and Conservation Strategy*). The monitoring recommendations from the CMARP work teams are summarized for each program and are presented in the corresponding sections of this chapter. Each section addresses the following topics:

- CALFED mission, goals and objectives--Relevant CALFED goals and objectives that are addressed by the proposed monitoring are listed. In some cases, monitoring for one CALFED program may fulfill goals and objectives of other CALFED programs.
- Goals and objectives of monitoring plan--The goal of the proposed monitoring, or how the monitoring plan addresses CALFED goals, is explained.
- Monitoring elements--The major elements of the monitoring for each common program with references to the more detailed appendices are provided.
- Research questions--The most important research questions for each common program are listed.
- Linkages among program elements--The linkages between monitoring for a particular CALFED program and the monitoring proposed for other CALFED programs are specified. Identification of the linkages is important for integration of monitoring elements into a cohesive plan.

As described in Chapter 3, thirty work teams were convened to develop detailed monitoring plans, which appear as appendices to this report. To provide a broad overview of the monitoring recommendations from all of the CMARP work teams, Table XXX summarizes the recommended monitoring elements and integrates the elements with the indicators proposed by the CALFED ERP Indicators Group. The monitoring elements in Table XXX are organized under eight major headings: Biota, Geomorphology, Energetics and Nutrient Cycling, Habitat, Human Welfare, Hydrology, Land use & Resource Management, and Meteorology, and classified further into categories. For example, Biota is sorted into Alga, Birds, Fish, etc.

Table XXX. Summary of Monitoring Elements recommended by CMARP work teams and merged with indicators proposed by the CALFED ERP Indicators Group. The monitoring elements are arranged under the general headings of Biota, Geomorphology, Energetics & Nutrient Cycling, Habitat, Human Welfare, Hydrology, Land use & Resource Management, and Meteorology with each general heading further organized into categories. Work teams are organized by CALFED Program (**DL:** Delta Levees; **ERP:** Ecosystem Restoration Program; **WM:** Watershed Management; **WQ:** Water Quality; **WT:** Water Transfers; **WUE:** Water Use Efficiency). Indicators Group designations are: DE=Delta, SFBE=Greater San Francisco Bay, ARFE=Alluvial River-Floodplain Ecosystem, URFE=Upland River-Floodplain Ecosystem; No designation means all systems.

	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
BIOTA				
1	Alga	Community survey, assessment	**WQ:** Sacramento River **ERP:** Benthic Macroinvertebrates	Trends in the abundance, diversity, composition, and distribution of benthic invertebrate assemblages, by functional group
2	Birds	Abundance; select. Riparian species.; distribution; reproduction; species. Richness/diversity; percent breeding species; reproductive success; percent migrants, genetic diversity, guild structure; clutch size; behavior; sign;	**ERP:** Fluvial Geomorphology, Shallow Water Habitats	Trends in abundance, reproductive success, diversity, composition, and distribution of native resident and migratory birds; Population trends of selected listed species
3	Contaminants (Tissue)	**Birds**-Organochlorines, Hg, Se, in eggs/reproduction; **Fish**-bioaccumulation of metals, trace elements, organics, Hg, PCB's, chlorinated insecticides, bioassessment surveys, exposure effects **Invertebrate-bivalves**-bioaccumulation of metals, trace elements, organics, exposure effects; **Invertebrates**-bioassessment	**ERP:** Estuarine System Productivity **WQ:** Contaminants, Sacramento River, San Joaquin River	Toxicity Concentrations in water and sediment Tissue concentrations Bioassays Biomarkers Bioindicators Contaminant loading
4	Delta Smelt	Adult, juvenile, larval, spawning	**ERP:** Delta Smelt	Population trends of selected listed species (DE); Presence/distribution of native and migratory fish species (DE); Number of unnatural barriers interfering with natural movements of native species, water flow, sediment transport and supply, and nutrient transport (DE); Trends in abundance, diversity, composition, distribution and trophic structure of native resident and anadromous fishes (DE, SFBE); Cohort survival & replacement rates selected fish/life stages (DE)
5	Fish	Community survey; condition indices; diet; feeding success; distribution & abundance; health; growth rate; relative abundance; fish ladder; 4 life stages; screen sampling at CVP and SWP; lamprey spawning; introduced species; flux; secondary production; reproductive success; biomass	**ERP:** Estuarine System Productivity, River Resident Fish, Steelhead, Fluvial Geomorphology, Fish X2, Hydrodynamics, Shallow Water Habitats **WQ:** Contaminants, San Joaquin River	Trends in abundance, diversity, composition, distribution and trophic structure of natives resident and anadromous fishes; Presence and distribution of native and migratory fish species; Length of river channel obstructed by artificial barriers; Length of riparian corridor unobstructed by artificial barriers; Population trends of selected listed species; Number of unnatural barriers interfering with natural move- ments of native species, flow, sediment & nutrient transport/supply (DE), Cohort replacement & sur- vival rates of selected life stages of certain fish (DE)
6	Introduced Species	Presence of non-indigenous species--monitor floating docks & buoys, shallow water margins, small water bodies, small tributary rivers and sloughs, artificial or altered lagoons, shipping facilities & ship exteriors, ship ballast water discharges & seawater system, baitworm seaweed & water packing; percent non-indigenous species; Update species identification keys; Adapt current monitoring to identify non-indigenous species.	**ERP:** Shallow Water Habitats, Non-Indigenous Species, Fluvial Geomorphology	Invasive introduced species: -Measures of new invasions -Abundance, spatial extent and distribution of selected species -Number of selected species eradicated or exhibiting no net increase in distribution

#	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
7	Invertebrates	Benthic fauna, biomass, size distribution, dominant species, composition and abundance; mysid abundance; macroinvertebrate production, community analysis, condition indices; terrestrial invertebrate abundance; secondary production	**ERP:** Salmon, Benthic Macroinvertebrates, Fish X2, Estuarine System Productivity, Shallow Water Habitats **WQ:** Contaminants	Trends in the abundance, diversity, composition, and distribution of benthic invertebrate assemblages, by functional group (DE, SFBE); Trends in the abundance, diversity, composition, and distribution of riparian insect assemblages, by functional group (URFE, ARFE); Population trends of selected listed species; Secondary production of zoobenthos (DE, SFBE)
8	Microbial	Communities; production	**ERP:** Estuarine System Productivity, Fish X2	
9	Phytoplankton	Biomass; exposure effects; primary productivity; species composition; assemblages	**ERP:** Fluvial Geomorphology, Estuarine System Productivity, Shallow Water Habitats **WQ:** Contaminants	Trends in abundance, diversity, composition, and distribution of native phytoplankton and zooplankton assemblages (DE, SFBE); Primary production rates (DE, SFBE)
10	Salmon & Steelhead	Escapement surveys; carcass surveys; delay in migration; outmigration surveys; trap efficiency; fry emigration; juvenile trawling; population density & emigration; juvenile distribution, growth, lipid storage, & stranding rates; maturity at out -migration, outmigration timing, survival; ocean harvest; ocean prey abundance; straying; pre-spawning mortality; percent hatchery fish in escapement; redd distribution & superimposition; redd stranding rates & spawning disruption; egg viability; running time; age composition; smolt survival; smoltification timing; dietary analysis; adult scale otolith production & analysis- adult & juvenile; steelhead/rainbow trout allelic testing; angler survey; distribution and emigration timing; post-spawning adult steelhead; steelhead hatchery marking; steelhead/rainbow trout lifestage ranking; spawning escapement;	**ERP:** Salmon, Steelhead	Population trends of selected listed species; Presence and distribution of native and migratory fish species; Number of unnatural barriers interfering with natural movements of native species, water flow, sediment transport and supply, and nutrient transport (DE); Cohort replacement and survival rates of selected life stages of certain fish (DE)
11	Vegetation	Bioassessment; cover; productivity; biomass; riparian structure, growth, productivity, stand attributes, tree size distribution, population dynamics, upland land cover and structure; vegetation changes after flooding;	**ERP:** Fluvial Geomorphology, Steelhead **WM:** Watershed Mgmt **WQ:** San Joaquin	Trends in distribution, diversity, and structural complexity of native plant associations; Population trends of selected listed species
12	Terrestrial & Aquatic Species	Trophic structure; mitigation for levee improve-ments; occupancy by habitat; harvest of wild & introduced species; individual morphometry; species distribution & abundance: plants, small mammals, fish, invertebrates, riparian insects, birds, amphibians, reptiles; percent exotic species; genetic diversity for mammals; wildlife-incidence of diseases & deformities;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Shallow Water Habitats **WM:** Watershed Mgmt	Trends in the abundance, diversity, composition, and distribution of native mammals (URFE, ARFE, DE); Fish and wildlife health; Population trends of selected listed species
13	Zooplankton	Presence/absence; abundance; exposure effects; community; species abundance; biomass; size composition; secondary production; flux	**ERP:** Estuarine System Productivity, Fish X2, Salmon, Hydrodynamics **WQ:** Contaminants	Trends in abundance, diversity, composition, and distribution of native phytoplankton and zooplankton assemblages (DE, SFBE); Abundance of zooplankton (DE, SFBE)

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	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
		ENERGETICS & NUTRIENT CYCLING		
14	Energetics & Nutrient Cycling	Carbon pools; dynamics; fixation; detritus composition, transport; organic carbon input; chlorophyll, primary production & nutrients(C,P,N) in water column; amount of litter accumulation in floodplains; nutrients(C,P,N) in floodplain soils;	**ERP:** Fish X2, Fluvial Geomorphology **WM:** Watershed Management	Nutrients from salmon carcasses(URFE); Organic input from grazing animals (URFE); Ratios of natural to anthropogenic sources of nutrients (URFE); Ratio of floodplain to river production (ARFE); Export of organic materials from floodplain to river channel (ARFE); Percent increase in dissolved N and P after overbank flows (ARFE); Concentrations of dissolved N and P in groundwater at selected sites (ARFE); Flux of detrital organic matter (DE, SFBE); Nutrient loading (DE)
		GEOMORPHOLOGY		
15	Aquifers	Boundary delineation & compaction; regional and local mapping of hydrogeologic boundaries; thickness and degree of confinement	**WT:** Water Transfers	
16	Channel	Bathymetric surveys; structural complexity; channel & bank stability & erosive resistance; channel incision in meadows & swales; morphology & migration; substrate complexity; geometry; habitat delineation; areal extent; channel changes after flooding; cross-sectional profile; longitudinal profile; channel density; network order; surface roughness	**DL:** Delta Levees **ERP:** Hydrodynamics, Salmon, Benthic Macroinvertebrates, Steelhead, Fluvial Geomorphology, Shallow Water Habitats **WM:** Watershed Mgmt	Mean width of available meander corridor (ARFE); Percent of river length not constrained by constructed levees (ARFE); pool to riffle ratio (URFE); Inter-annual comparison of fluvial geomorphic features (URFE); Percent of river miles exhibiting naturalistic meandering (ARFE); Linear distance of channels per unit area (DE); Proportion of 1st, 2nd, 3rd order channels/ unit area(DE); Bank slope(DE)
17	Land	Subsidence; land surface altitude; topographic/geologic characterization;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology **WT:** Water Transfers **WM:** Watershed Mgmt	Difference in percent of area flooded during MHHW versus MLLW (DE)
18	Levees	Identification of vulnerable zone; assessment of restoration efforts; mapping of ground-shaking	**DL:** Delta Levees	
19	Sediment	Composition; grain size; particle size distribution; deposition/mobilization dynamics; floodplain, bank, channel deposits; organic sediments; Contaminants (Se, organochlorines, resuspension mercury); toxicity; trace elements & metals; ionized ammonia, total sulfides, total organic carbon, total nitrogen; suspended sediment bedload & solute load; substrate permeability; resuspension; sediment production background rates; sediment pH; flux; bioturbation depth; depth of detritus; redox potential; bulk density; chemistry	**ERP:** Estuarine System Productivity, Salmon, Fluvial Geomorphology, Shallow Water Habitats, Hydrodynamics, **WQ:** Contaminants, San Joaquin River, Sacramento River **WM:** Watershed Mgmt	Bedload movement (URFE); Sediment particle size and distribution (URFE, ARFE); Net change in depth per unit time of unconsolidated sediment (URFE, ARFE); Amount of coarse sediment delivered (as a proportion of pre-dam) (ARFE); Lateral exchange: river to floodplain (ARFE); Inter-annual comparison of fluvial geomorphic features (ARFE); Marsh plain & mudflat elevation relative to sea level (DE, SFBE); Change in area of Delta islands and islets (DE); Net sediment accretion rate relative to rate of sea-level rise at subtidal and intertidal sites (SFBE);
20	Seismic	Delta ground motions; source characterization	**DL:** Delta Levees	
21	Soils	Peat & organic gradation, oxidation, organic matter content, moisture content, void ratio, compressibility, vertical and horizontal extent; stability and erosive resistance; accretion	**DL:** Delta Levees **WM:** Watershed Management	

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	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
		HABITAT		
22	Habitat	Channel morphology; river habitat vs. fish assemblage; floodplain inundation; fish habitat availability and micro-habitat usage below dams; spatial extent and configuration; compensatory mitigation for levee improvement including mitigation banking; salmon spawning restoration projects; salmon spawning sediment substrate sampling; vegetation- horizontal cover and vertical structure; canopy cover; riparian forest width, height, density; areal extent of wetlands and seasonally wet environments; riparian habitat delineation & areal extent; detritus & debris; shoreline development; total shoreline length, horizontal accretion & erosion; patch temporal variability; patch classification, size frequency, diversity; floodplain habitat proximity to topographic features, e.g. location of the thalweg & littoral zone; occurrence of unnatural barriers interfering with movements of native species	**DL:** Delta Levees **ERP:**Steelhead, Fluvial Geomorphology, Salmon, Shallow Water Habitats, Benthic Macroinvertebrates **WM:** Watershed Mgmt	Extent and distribution of patches of all natural habitat types; presence and distribution of species requiring multiple habitats; Abundance, distribution, and recruitment rate of large woody debris (URFE); Shaded riverine aquatic habitat (URFE); Diversity of flow velocity (URFE); Distribution and extent of floodplain habitats (ARFE); Distribution and extent of littoral zone (ARFE); Percent of river length not constrained by constructed levees (ARFE); Connectivity of riverine channels to wetlands (DE)
		HUMAN WELFARE		
23	Agriculture	Number and size of farms; value of agricultural output; agricultural employment; labor force and unemployment; social and economic values related to agricultural practices	**WM:** Watershed Management **WT:** Water Transfers	
24	Flood	Flood fighting support;	**DL:** Delta Levees	
25	Health	Risk assessment for Hg, Se; Mitigation of Se inputs into ducks, crabs & fish;	**WQ:** Contaminants	Toxicity: Concentrations in water, sediment, tissue, bioassays, Biomarkers, Bioindicators, Contaminant loading; Dissolved oxygen; Turbidity-suspended solids; Nutrients (N, P, C); Salinity/TDS
26	Water Transfer Effects	Income; rural businesses sales and employment; social & economic values related to community involvement, watershed management, water use practices, recreation, habitat extent & species diversity; water transfer history & third party effects	**WM:** Watershed Management **WT:** Water Transfers	
		HYDROLOGY		
27	Bay-Delta Hydro-dyamics	3D-Hydrodynamic Model; bottom salinity/ temperature axis of north channel; delta water export rates; historical bay-delta hydrodynamics studies; horizontal current patterns; ocean currents; sea level rise; shallow water hydrology; tidal prism conservation; hydroperiod; tidal regime; tidal prism; water depth; wetted area;	**DL:** Delta Levees **ERP:** Hydrodynamics, Salmon, Shallow Water Habitats	Water movement and vertical mixing at select locations throughout Bay (SFBE)
28	Groundwater	Discharge & recharge; levels; movement; water quality; sources; wetland storage & sreambank storage;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology **WM:** Watershed Mgmt **WT:** Water Transfers	Depth of water table (ARFE); Soil moisture levels, laterally from banks (ARFE); Characteristic plant communities (ARFE); Width of riparian corridor (ARFE)

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	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
29	Flow	Flooding regime; daily flow; depth; diversions & withdrawals; export rates; episodic rates; installation & removal of barriers; flow gate operation; inflow rate; net tidally averaged; peak flows; pulsing; river time series; stage (height); discharge; velocity; velocity profiles; vertical hydraulic gradient; tidal time series flow; runoff; evaporation; infiltration; flood frequency; channel tidal flows, velocity & stage; changes due to setback levees, net infiltration; characterization of low flows;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Estuarine System Productivity, Salmon, Hydrodynamics, Benthic Macroinvertebrates, **WM:** Watershed Mgmt **WQ:** Contaminants, San Joaquin River, Sacramento River **WT:** Water Transfers,	Minimum base flows (URFE, ARFE); Seasonal shifts in river level (URFE, ARFE); Measures of variability (URFE, ARFE); Geographic distribution of flows (ARFE); Delta outflow (DE); X2 location (SFBE); Salinity at selected locations throughout the Bay (SFBE); Minimum surface area of floodplain inundated at least once every 2 years and every 10 years (ARFE); Flood duration (mean and variability) (ARFE); Mean annual frequency of floods (ARFE); Composite measures for freshwater flow rates, water residence time, and flow direction for selected channels (DE); Flows of tributaries mimic pattern of unimpaired flow (DE);
30	Reservoirs	Surface water; storage; water quality; temperature	**WM:** Watershed Mgmt **WT:** Water Transfers	
31	Suspended Sediment	Delivery & types to impoundments; inflow into delta; within delta;	**ERP:** Hydrodynamics **WM:** Watershed Mgmt	
32	Water Deliveries	Surface water;	**WT:** Water Transfers	
33	Water-Contaminants	Ambient surface water for pesticides; aquatic toxicity; bromides; contaminant transport; dissolved and total organics; dissolved and total trace elements/metals; mercury including methyl-mercury; organochlorines; pathogens; impacts due to dredging; THMFP; toxicity to invertebrates, alga, & fish; undissociated ammonia levels	**DL:** Delta Levees **ERP:** Salmon **WM:** Watershed Mgmt **WQ:** Contaminants, San Joaquin River, Sacramento River	Toxicity: Concentrations in water and sediment, Tissue concentrations, Bioassays, Biomarkers, Bioindicators, Contaminant loading
34	Water-Chemistry	Alkalinity; conductivity; dissolved oxygen; hardness; major ions; nutrients; nutrients-organics; organic carbon/BOD; salinity; solutes; total organic carbon; strontium in steelhead spawning streams; chlorophyll	**ERP:** Fluvial Geomorphology, Benthic Macroinvertebrates, Fish X2, , Salmon, River Resident Fish, Estuarine System Productivity, Steelhead **WM:** Watershed Mgmt **WQ:** San Joaquin Water River Sacramento River **WT:** Water Transfers	Salinity at selected locations throughout the Delta (DE)
35	Water-Physical	Light attenuation; total dissolved solids; total suspended solids; turbidity; temperature	**ERP:** Fluvial Geomorphology, Estuarine System Productivity, Steelhead, Hydrodynamics, River Resident Fish, Salmon, Benthic Macroinvertebrates **WQ:** San Joaquin River, Sacramento River **WM:** Watershed Mgmt **WT:** Water Transfers	Dissolved oxygen; Turbidity-suspended solids; Nutrients (N, P, C); Salinity/TDS
		LAND USE & RESOURCE MANAGEMENT		
36	Agriculture	Land use/acreage by irrigation methods; irrigation amounts & efficiency; CIMIS; crop patterns; environmental & third party impacts of water transfers; real time Eto; EWMP implementation; grazing & management practices; length of canals & laterals; pesticide management effectiveness; reduction in applied water, groundwater depletion; surface & subsurface drainage; delta land use, soils, water use surveys;	**WM:** Watershed Management **WQ:** Contaminants **WT:** Water transfers **WUE:** Water use efficiency	

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	Category	Monitoring Elements	CMARP Work Teams	Proposed Indicators (ERP Indicators Group)
37	Land use	Land use vs. water quality; human activities near streams & riparian areas; logging & practices; mining; point sources of sediments & contami- nants; recreational land use; presence & type of activity by habitats; roads & road-building; water -shed improvement practice; wildfire & fire suppression; land management practices; land use history; personnel turn over; land use intensity; funding;	**ERP:** Fluvial Geomorphology, Shallow Water Habitats **WM:** Watershed Mgmt **WT:** Water Transfers	
38	Levees & Impound-ments	Impoundments; levee cross-sections; levee maintenance quality inspections; levee profiles; ground failure mapping;	**DL:** Delta levees **WM:** Watershed Mgmt	
39	Population/ Demographics	Population; population within water service area boundaries; income	**WT:** Water transfers **WUE:** Water use efficiency	
40	Urban	Applied water reduction; BMPs; commercial, industrial, & institutional customer data; Eto data for surveyed landscapes and applied water; reduction in groundwater depletion; interior water use; irrigated landscape acreage surveys; urbanization; water management plans; water use per capita data by customer class, water district, hydrologic region; water use efficiency estimates;	**WM:** Watershed Mgmt **WUE:** Water use efficiency	
41	Water Recycling & wastewater	Amount produced/used in supplier service area, individual water reclamation projects, local water recycling projects; quality of source water & re- cycled water; wastewater collected/treated; recycled wastewater use benefits; wastewater discharge; nutrient loading from sewage, cannery effluent, urban runoff, dairy farms; Mercury NPDES discharges	**ERP:** Salmon **WQ:** Contaminants **WUE:** Water Use Efficiency	
		METEOROLOGY		
42	Air	Mercury deposition; organochlorine source loading; relative humidity; temperature; wind speed & direction	**ERP:** Estuarine System Productivity **WQ:** Contaminants	
43	Precipitation	Amount, timing & form; snow-pack & snow-melt dynamics, sunlight	**ERP:** Estuarine System Productivity **WM:** Watershed Mgmt	

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Chapter V, part B. Comprehensive Monitoring, Research and Assessment Program for the Ecosystem Restoration Program Plan

Goals of the Ecosystem Restoration Program Plan

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan for the restoration of ecosystem health and improve water management for beneficial uses of the Bay-Delta system. The Ecosystem Restoration Program Plan has been developed to address problems related to ecosystem quality. Ecosystem goals developed as part of the Strategic Plan for Ecosystem Restoration (1998) will guide implementation of the program. These strategic goals include:

1. Achieve large, self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay, support similar restoration of at-risk species in San Francisco Bay and the watershed above the estuary, and minimize the need for future endangered species listings by reversing downward population trends of non-listed native species.
2. Rehabilitate natural processes in the Bay-Delta estuary and its watersheds to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.
3. Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.
4. Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.
5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.
6. Improve and maintain water and sediment quality to eliminate to the extent possible, toxic impacts to organisms in the system, including humans.

The CALFED Ecosystem Restoration Program (ERP) proposes to reach these goals by restoration of the physical and ecological processes associated with the formation and maintenance of the habitats required by the diverse species dependent on the Bay-Delta and its associated watersheds. The ERP proposes to achieve this restoration through an ambitious program including a wide variety of actions in the context of adaptive management. The core idea behind adaptive management is to treat management actions as scientific experiments. This requires that the effects of each management action be monitored and the data assessed so that the success of the action can be determined and subsequent actions improved, if possible, in response to the knowledge gained. Also, the ERP recognizes that management of human activities are an integral component of ecosystem management. Thus, actions undertaken as part of other CALFED programs concerned with water quality, water supply reliability, and levee integrity should be closely linked to ERP.

Objective of the ERP Portion of CMARP

The complex and ambitious program of adaptive management proposed by CALFED and ERP in particular requires a significant investment in monitoring and research activities. Long-term, system-wide, baseline monitoring data are needed to determine if the overall goals are being met. Monitoring is needed to determine the effects and degree of success of specific actions and projects. Focused research is needed to increase understanding of ecological processes and consequently reduce uncertainty regarding the outcome of actions. As outlined in the Strategic Plan for Ecosystem Restoration (1998), all of these activities should be undertaken within a framework of developing conceptual models, developing testable hypotheses, testing the hypotheses by conducting focused research and learning from management actions, leading to improvement of conceptual models and more refined management actions.

The purpose of the ERP portion of the CMARP is to present an initial concept of the monitoring and research program required to implement, assess, and improve the ERP as adaptive management proceeds. The plan includes monitoring of physical processes that may change in response to CALFED actions, such as river flow below dams that can affect fluvial geomorphic processes. The plan includes monitoring of habitats affected by those processes, such as channel form and riparian vegetation. The plan also includes monitoring of the species dependent on the habitats, with additional emphasis on species of high concern.

The plan is programmatic in scope because a sequence of actions has not yet been defined. Thus, the plan is flexible and can be modified as the sequence of adaptive management experiments is implemented. For example, ongoing discussions in the Diversion Effects on Fishes Team include the concept of a comprehensive program of real-time monitoring of fish species of concern to aid in flexible operations of the water conveyance system. Such a program can not be designed until the data needs of the flexible operations plan is known but once the requirements of such a program are known, it can easily be designed and incorporated into the CMARP framework. This example also illustrates one linkage possible between ERP and the other CALFED programs.

The plan was developed by assembling small groups of experts to design discrete portions of the plan. Each team was asked to provide a conceptual model, a monitoring program, and a program of focused research for their topic (Appendices 1-14). Although all of the work team plans are excellent documents, we recognize that the short time available for developing them precluded the participation of many interested scientists and did not allow for outside review and revision of the plans. Thus, the initial concept developed here will likely continue to be revised and improved as CMARP moves into the implementation phase. Also, the work team assignments were made before the Strategic Plan for Ecosystem Restoration (1998) was available, so the goals and objectives addressed may not exactly match those presented in the body of this report. This is another example of why the plan needs to be flexible in response to refinements in ERP and CALFED in general.

The plan components can basically be divided into those concerned with river systems and those concerned with the Bay-Delta system. The ERP primarily limits consideration of river issues to the stream reaches downstream of the major foothill dams or equivalent elevations on undammed streams. Upstream reaches of rivers are covered by the CALFED Watershed Program; however, several work teams also included upstream river reaches in their plans to some degree. The major components of monitoring proposed for each type of system are presented below.

ERP-CMARP Program Components
Each of the work team products is summarized in the following sections. More detail is available in the appendices.

River Systems

Fluvial Geomorphology and Riparian Issues -- There is general agreement that dams, diversions and levees have stressed riverine aquatic ecosystems because of their effects on flow patterns and subsequently aquatic and riparian habitats. The objective of a number of CALFED actions is to re-establish natural flow patterns and associated habitat processes in regulated streams to improve habitat for anadromous fishes, resident fishes, other aquatic organisms, and terrestrial plants and animals. These processes include such things as stream meander, sediment recruitment and transport, floodplain inundation, and riparian forest succession. The work team was careful to observe that even though these processes are understood in a general sense, application of the concepts to specific streams may result in unexpected results. Many of the concepts of fluvial geomorphology are best applied to free-flowing streams and the concepts may have to be adapted to regulated streams. The degree to which natural function can be restored to systems in the CALFED solution area is unknown in some cases because present conditions have been so altered from natural conditions. For example the floodplains of some streams have been elevated by past hydraulic mining activities such that restoration of natural flows would not result in a natural pattern of floodplain inundation. The biological processes involved in such manipulations are less well understood than the physical processes.

The work team addressed monitoring and research needs for Central Valley streams from the elevation of the major foothill dams downstream to the legal Delta. The emphasis of the fluvial geomorphology recommendations is on the gravel-bed reaches of the streams and additional emphasis on soft-bottomed reaches may be appropriate as the program develops. Because of the large area and many streams in the CALFED solution area the plan adopts a nested design with a relatively coarse-grained monitoring effort over the large area and more detailed monitoring and research at specific sites.

Periodic stereoscopic aerial photography of all significant streams of interest will provide the backbone of the monitoring plan. Aerial photography is compatible with geographic information systems and can provide relatively detailed information on topography, channel form, and riparian vegetation. The data obtained from aerial photographs can be applied at a variety of scales from the landscape level to the project-specific level. Although detailed characterization of instream conditions (e.g. water depth, water velocity, substrate) is not possible with photographs, general habitat characterization of stream reaches would be possible including stream width, sinuosity, and general habitat types at several scales of detail (Appendix 1). Riparian vegetation data can be analyzed to provide a variety of indices including areal extent and measures of connectivity. Both of these measures could also be used as indicators of program progress and success. These data could be correlated with information on topography, soil type, and geological formations to clarify our understanding of what types of riparian vegetation to expect under different circumstances. Comparison of aerial photographs taken during high and low flows could be especially useful in defining the extent of floodplain habitat available. Aerial photography should be repeated periodically. The work team tentatively suggested five-year intervals; however, flood events should also trigger new photography. Fluvial geomorphic processes are largely driven by large flow events; thus, floods may result in significant changes that should be documented as soon as possible. In addition, new or supplemental photography might be required to document management actions.

In addition to the landscape-level measurements based on aerial photography, the work team suggested more detailed measurements at a number (40-50) of long-term monitoring sites. Because long-term access to the sites would be essential, the choice of sites might be biased toward areas where access could be assured rather than a scientifically-based selection of sites. Two types of sites were identified: geomorphic and riparian. Ideally, a single site could serve both functions. These sites could actually fulfill several functions depending on management actions. The sites could serve as long-term monitoring sites for baseline conditions or could serve as comparison sites for projects within the same or nearby reaches of stream.

The work team proposed a variety of data to be collected at the sites. For geomorphic purposes the work team identified detailed channel morphology, stage-discharge curves (the relationship between water level and stream flow), floodplain morphology, and substrate composition as important variables. There was a separate need identified for monitoring of the physical habitat and biota in floodplain areas and flood bypasses but specific variables and methodologies for monitoring were not identified. For riparian sites, tree species composition and trunk diameter, shrub species composition and basal area, percent cover by herbaceous species, and various growth and productivity measures were suggested. The work team plan (Appendix 1) provides some suggested methodologies for many of these measurements. The work team also observed that an adequate network of stream flow gages throughout the study area is essential to the calculation of many hydrologic parameters and interpretation of the monitoring data gathered.

In addition to monitoring geomorphic processes and riparian plants, animals should be monitored as well. The work team provided a plan for monitoring of birds. Plans for river resident fishes, including anadromous lampreys, and anadromous salmonids are presented separately below. The work team provided general guidelines for integrated monitoring of habitats, species, and communities that are compatible with what is being proposed for the Watershed Program.

The work team identified several areas where research or assessment of existing data were necessary (Appendix 1). Briefly these are: 1) test a methodology for assessing the effect of water development on flow regime; 2) compile and assess temperature data and existing data collection activities; 3) river-groundwater exchange processes; 4) groundwater (hyporheic zone) ecology; 5) recruitment dynamics of riparian vegetation; and 6) fish use of floodplain habitat. Justification for each research component is provided in the Appendix with a detailed proposal presented for item 6.

This work team product is closely related to several other ERP work team products including River Resident Fishes, River Benthic Macroinvertebrates, and the anadromous fishes work plans. In addition, this work team product is linked to several other CALFED Programs besides the ERP. Decisions within Storage and Conveyance and Water Transfers may affect patterns of stream flow and associated geomorphic processes on particular streams that may have to be monitored within the program. These Programs also have the potential to affect groundwater levels which can effect riparian vegetation. Monitoring of plants and animals must be coordinated with priorities set by the Conservation Strategy to make sure that special status species are adequately monitored within the larger framework of community monitoring. Finally, this work plan must be as compatible as possible with the upstream reaches of the streams, included within the Watershed Program, and the Bay-Delta system, addressed by separate ERP components below. Linkage with the Water Quality Program is less direct with sedimentation and water temperature the most obvious areas of overlap.

River Benthic Macroinvertebrates -- Bioassessments of benthic macroinvertebrate communities are commonly used tools for monitoring of water quality and evaluation of watershed condition. Individual species of benthic macroinvertebrates are sensitive in varying degrees to water temperature, dissolved oxygen, sedimentation, scouring of the streambed, nutrient enrichment and chemical and organic pollution. Benthic macroinvertebrates are also important for their own sake and can provide a wealth of evolutionary, ecological, and biogeographical information. In addition, benthic macroinvertebrates represent a significant food source for aquatic and terrestrial animals.

Given the importance of benthic macroinvertebrates to aquatic and terrestrial ecosystems and their usefulness for bioassessments of ecological and water quality conditions, California's fauna remains relatively poorly studied. Most bioassessment procedures using benthic macroinvertebrates have been developed in the eastern United States. Research is needed to develop reliable relationships between benthic macroinvertebrate communities and environmental conditions. Also, additional work is needed on taxonomy of western species.

The work team proposed a basic program of monitoring and research (Appendix 2). The suggested scale of monitoring is the watershed which would require coordination between ERP and the Watershed Program. The work team also recommended some specific protocols for site selection, sampling methodology, and sampling frequency. In addition to sample collection, physical and water quality conditions at each site should be characterized as completely as possible, including at a minimum: water temperature, pH, turbidity, specific conductance, water depth, water velocity, substrate characteristics, and canopy cover. Coordination of site selection and sampling with that of the fluvial geomorphology program and monitoring suggested in the Water Quality Program would efficiently provide even more data on physical and chemical conditions associated with benthic macroinvertebrate communities. Data analysis in the early part of the program would focus on establishing relationships between species abundances and biological metrics of community structure with watershed characteristics and physical and chemical parameters. As knowledge is acquired, appropriate models or indices can be developed to provide a standardized measure of the condition of the benthic macroinvertebrate community.

Simultaneously with the monitoring effort, several research topics should be pursued. Additional information on the taxonomy and distribution of California benthic macroinvertebrates is needed from all Central Valley watersheds. Surveys should include both larval and adult forms and organisms should be identified to the species level. This research is needed to better understand the species diversity present in the study area. This research will also provide information on exotic species. Because of the limited work on taxonomy and distribution of benthic macroinvertebrates, the presence and potential importance of exotic species in benthic macroinvertebrate communities of the river systems is largely unknown. Research is also needed to determine the sensitivity of western species of benthic macroinvertebrates to various types of environmental degradation.

The work team identified several metrics of benthic macroinvertebrate communities that are commonly used as indicators in bioassessments. These metrics may also serve as useful indicators of benthic macroinvertebrate community condition for ERP and include taxa richness, Shannon Diversity Index, EPT taxa (total number of distinct taxa in the insect Orders Ephemeroptera, Plecoptera, and Trichoptera), EPT Index (proportion of total number of individuals in EPT taxa), Modified Hilsenhoff Biotic Index (HSI), and Percent Dominant Taxon (PDT) (the percentage of total individuals represented by the most dominant taxon). See Appendix 2 for more details.

As noted earlier this monitoring element is closely linked to the fluvial geomorphology monitoring element, the Water Quality Program, and the Watershed Program. It is worthwhile to note that the Water Quality Program independently identified bioassessments of benthic macroinvertebrates as a water quality monitoring tool.

River Resident Fishes -- Surprisingly little is known about the native and introduced fishes residing in Central Valley rivers and streams. Most monitoring and research efforts have been focused on anadromous salmonids and other species with special status of some kind (e.g. Sacramento splittail proposed for federal listing). The emphasis of the ERP on ecosystem management, ecosystem processes, and preventing decline of currently unlisted species of fish and other taxa will require monitoring and research on river resident species (including anadromous lampreys). Fish communities have also been used as bioindicators of environmental conditions and the Water Quality Program has suggested bioassessments of fish communities be used in their water quality monitoring program.

The work team presented separate conceptual models for the San Joaquin, Sacramento, and Mokelumne river watersheds but the models were based on common hypotheses of how resident fishes, both native and introduced, respond seasonally and annually to environmental conditions including flow regime, physical habitat, water quality, and interactions with other species (Appendix 3). The monitoring program was designed to simultaneously begin to build the long-term data base required to assess the success of management actions and provide the information needed to continue to refine the conceptual models and increase understanding of ecological processes.

The work team proposed a long-term, geographically extensive program of monitoring to assess the distribution and relative abundance of river resident fish species and to detect new exotic species as they enter the system. A variety of sampling methodologies were suggested including electrofishing, seining, snorkeling, gill netting, and various traps. The work team noted that there may be institutional barriers to the use of some of these methods depending on the presence of special status species, particularly anadromous salmonids. In addition to the collection of routine information such as species identification, counts, lengths, and weights, the work team suggested additional activities including assessment of fish condition/health, aging of fish, diet analysis, and tagging as useful in relation to both monitoring and research.

Monitoring of river resident fishes was suggested for all streams being monitored for anadromous fishes with sampling efforts conducted in cooperation whenever possible. Additional monitoring should be conducted on a prioritized set of the remaining streams depending to some extent on proposed management actions and the ability to locate monitoring sites at locations where other monitoring elements are being conducted. The work team identified access to private land as a practical impediment to site selection that might have to be incorporated into the stream prioritization. The work team emphasized that monitoring of resident fishes should be conducted in concert with monitoring of anadromous species, water quality, benthic macroinvertebrates, fluvial geomorphology, and riparian habitat. This cooperative approach provides the greatest opportunity to associate changes in fish communities with changes in environmental conditions.

Temporal frequency of monitoring was also mentioned by the work team as an important aspect of the program. While it is possible that a single summertime sample might be sufficient to characterize annual variation in the resident fish assemblage, such an annual sampling would not lead to understanding of the ecological processes resulting in the observed community structure and its response to management action. The work team suggested monthly sampling as the most desirable sampling frequency but also identified monthly spring-summer (March-September sampling as an appropriate intermediate frequency. The work team indicated that this intensity of sampling should continue annually over a variety of water year types but also recognized that this high level of effort might only be practical on a limited number of streams within the program.

The work team identified several areas of research that would be useful in interpretation of the monitoring data and in understanding the responses of resident fishes to management actions. Briefly these are (see Appendix 3 for details): 1) compilation and additional research on the life history and physiology of resident species so their responses to environmental conditions can be better understood; 2) clarify the population structure (genetics) of species of concern; 3) development of an Index of Biotic Integrity or similar index as an indicator of resident fish community condition; 4) evaluate techniques for assessment of fish health/condition; 5) experimentally test causal relationships suggested by monitoring data and observational studies; 6) document the sources and effects of new exotic species as needed; 7) assess the effects of commercial or recreational exploitation as appropriate for selected native and exotic species.

The work team suggested several possible indicators for resident fishes. An Index of Biotic Integrity or similar multimetric index could be developed. Percentage of native fish and percentage of intolerant fish (species sensitive to environmental stress) are other possible general indicators. Measurement of fish health/condition can also serve as good general indicators. Map presentations of the geographic distribution of the various fish communities can provide a useful summary of complex fish community data.

The work team identified linkages to a wide range of other monitoring elements. Within the ERP, linkages were identified to the riverine benthic macroinvertebrate element, steelhead element, chinook salmon element, fluvial geomorphology and riparian issues element, Bay-Delta fishes element, and Bay-Delta shallow-water habitat and watersheds element. This program would also be linked to any independent element concerned with nonindigenous species. Linkages to other programs included the Watershed Program and the Water Quality Program.

Chinook salmon – Fall-run chinook salmon are probably the most studied fish in the Central Valley. Thus, the conceptual models, monitoring, and research proposed for this species are the most detailed of any presented for the monitoring elements concerning river systems (Appendix 4). The monitoring elements for the other salmon runs are not as well developed because detailed investigations of their biology in the Central Valley has begun quite recently as they have acquired special status (federal or state listing). Understanding of these other runs can begin with extensive data from other systems outside California or can begin with concepts developed for fall-run chinook salmon. Similarly, little information is available for Central Valley steelhead. The chinook salmon work team considered steelhead needs in their plan but a separate steelhead plan (below) was also prepared to highlight the needs for proper understanding of steelhead needs.

The conceptual model presented by the work team focuses on the fall-run chinook salmon and is based on an extensive review of the existing literature and other information on Central Valley chinook salmon. The conceptual model adopts a life-stage approach and identifies key hypotheses and assumptions for monitoring or research for each life stage. Briefly, the key issues identified for each life-stage are (see Appendix 4 for details): 1) upstream migration of adults – straying, delayed migration, egg viability, migration barriers, and prespawning mortality; 2) spawning – altered flows, degraded channel complexity, high water temperatures, gravel recruitment, harvest and harassment, and altered genetics due to hatchery fish; 3) incubation and emergence – high water temperatures, fine sediment intrusion, gravel recruitment and instream gravel mining, intrusion of oxygen-poor groundwater into redds (nests), excessive gravel mobilization during high flows, and reduced habitat complexity; 4) juvenile rearing – stream flow and interactions with floodplains, high water temperatures, contaminants, food supply, and disease; 5) juvenile migration – stream flow, predation, unscreened diversions, stranding, and water temperatures. Juvenile migration through the Bay-Delta is covered by a separate monitoring element below. The work team also noted that ocean residence can have very important effects on chinook salmon populations.

The chinook salmon plan for the river phase of their existence (Bay-Delta phase addressed separately below) includes extensive recommendations for monitoring the abundance of juvenile and adult chinook salmon and for monitoring key features of salmon health, habitat quality, and ecosystem processes. These data will provide a basis for adaptive management (see Appendix 4 for details). The suggested monitoring elements covered each life stage separately. Suggested adult monitoring included coordination with existing CAMP (and other ongoing programs) carcass surveys and implementation of additional surveys on streams not included in CAMP, evaluation of new or additional methods for estimating adult abundance, and analysis of scales and otoliths to verify age structure of the runs. Monitoring of spawning activity should include documentation of the distribution of redds within and between riffles so the extent of spawning habitat can be determined and under-utilized habitat identified. The work team identified several parameters to be monitored in representative riffles of streams where spawning habitat restoration projects are funded and unsuitable intragravel water quality exists: intragravel dissolved oxygen concentration, intragravel water temperatures, substrate permeability, and vertical hydraulic gradient. The work team suggested an annual assessment of the overall abundance and health of juvenile salmon using a variety of techniques at monthly intervals from February through June. Coordination with rotary screw trapping by CAMP and other programs would be part of this activity. Recommendations for monitoring of juvenile migration mainly concerned improving the capture efficiency of existing and proposed rotary screw trapping to increase accuracy of estimates. Work team recommendations for monitoring juvenile survival included recommendations for activities in both the river and the Bay-Delta system. The river recommendations included mark-recapture studies of hatchery and wild fish (as available) using several different group sizes of release. Radio tagging was also recommended in streams where outmigrants of appropriate size are available.

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Monitoring of ocean conditions such as ocean harvest, ocean currents, and prey abundance, was also mentioned as an important activity.

The work team prepared a very detailed set of research topics (Appendix 4). The research topics were derived from the assumptions and hypotheses forming the basis of the conceptual models presented. The research topics were summarized under the following general categories: effects of fluvial geomorphology, effects of predation, effects of water temperature, factors effecting smolt survival, instream flow studies, genetic evaluations, adult tagging studies, creel surveys, effects of contaminants, and incubation studies.

The work team provided a river by river list of existing chinook salmon activities that will help coordinate work and avoid duplication of effort (Appendix 4). The work team recommended five indicators: 1) trends in naturally-produced salmon and steelhead measured as escapement to rivers and the ocean and sport harvests; 2) trends in the number of "crashes" (catastrophic loss of a brood year) due to unsuitable environmental conditions; 3) trends in the egg-to-fry survival of naturally-produced salmon and steelhead (a methodology is proposed); 4) trends in the number of naturally-produced juvenile salmon and steelhead migrating out of rivers; and 5) trends in the survival of naturally-produced juvenile salmon and steelhead migrating through the rivers and Delta. The work team did not specifically identify linkages with other ERP monitoring elements and other CALFED programs but many such links were implicit in the discussions of monitoring and research. A list would be very similar to that for the river resident fishes element and would include within the ERP, the riverine benthic macroinvertebrate element, steelhead element, fluvial geomorphology and riparian issues element, Bay-Delta fishes element, and Bay-Delta shallow-water habitat and watersheds element. Linkages to other programs would include the Watershed Program and the Water Quality Program.

<u>Steelhead</u> – Similar to the river resident fishes, Central Valley steelhead have received relatively little study. Most data on steelhead come from other California river systems or areas outside of California. The work team prepared a detailed review of life history information, current status, and a discussion of stressors that serve the same purpose as a conceptual model (Appendix 5). The conceptual models prepared by the chinook salmon teams apply generally to steelhead because the species share an anadromous life history but there are some significant differences, especially in population structure and dynamics. Most importantly, however, are differences in the severity of impacts of stressors common to the two species (particularly those dealing with flow and temperature) which can be greater for steelhead because of the longer period of freshwater rearing by juveniles. The primary stressor identified for steelhead was large-scale loss of spawning and rearing habitat. Juvenile steelhead must rear in fresh water for one year or longer; therefore, water temperatures must remain in the tolerable range for the entire year. This is often not the case during late-summer and fall below the major dams.

The work team noted that the paucity of baseline monitoring data for steelhead was the result of two general constraints. First, chinook salmon receive the majority of funding for research and monitoring because salmon are highly valued by commercial and recreational anglers and thus are the object of various political actions. This narrow-focused monitoring effort was reinforced by the misconception that steelhead suffer from the same level of impacts as do chinook salmon, therefore assessment of impacts should be similar to chinook salmon. Second, the life history of steelhead makes them difficult to monitor. The work team listed a variety of ongoing monitoring and research programs concerned with anadromous salmonids and ranked their relative value to chinook salmon and steelhead (Appendix 5). There are 40 ongoing projects that collect at least some information on steelhead but only 8 are focused primarily on steelhead. This list provides a valuable compilation of possible cooperators to meet CMARP steelhead needs.

The work team identified six major knowledge gaps requiring either new monitoring and assessment programs or enhancements to ongoing anadromous fish monitoring programs. These are: 1) current distribution and abundance of naturally-spawning populations; 2) specific spawning and rearing habitat requirements and assessment of existing habitat; 3) genetic and population structure; 4) access and restoration of potential habitat currently above impassable dams; 5) the degree of straying of hatchery steelhead and the effects of straying; and 6) effects of water operations in the delta/estuary (see Appendix 5 for details). The work team also identified and described a comprehensive monitoring plan, for application in the tributary streams, mainstem rivers, and the Delta, as appropriate, that has two primary components: habitat monitoring and population monitoring. Habitat monitoring includes habitat typing and mapping, stream flow and temperature monitoring, and identification of other stressors important in specific situations (e.g. sedimentation). Population monitoring was described for several life stages, including spawning adults, juvenile rearing, and juvenile emigration. Changes in abundance, periodicity, and habitat availability, at each life stage, were identified as indicators by the work team. A detailed list of specific questions to be addressed with the monitoring program was also provided. In many respects the monitoring program proposed by the work team also serves as a research component because so little as known about Central Valley steelhead.

Bay-Delta System

Hydrodynamics – In recent years, workers in the Bay-Delta system have come to recognize that understanding hydrodynamics, the movement of water through the system, is central to understanding how sediments, salts, other chemicals, and organisms are distributed. This task is complicated by the physically complex and tidally driven nature of the estuary. In essence, hydrodynamics encapsulates the physical processes essential to the creation, maintenance and evolution of Bay-Delta habitats that are used by and determine the distribution of organisms.

The work team provided a detailed conceptual model of Bay-Delta hydrodynamics (Appendix 6). Within the conceptual model, two pivotal ideas are discussed. First, the conceptual model stresses the various temporal scales that have to be considered when trying to understand Bay-Delta hydrodynamics including the tidal (about daily) time scale, the fortnightly spring-neap tidal cycle, and annual and longer time scales. Daily patterns of winds are a complicating factor at the tidal timescale. Second, the conceptual model stresses spatial variability. Sources of spatial variability include the physical complexity of Delta channels which may considerable effects on dispersion, multiple flow paths through major channels in Suisun Bay, the interaction between shoals (shallows) and deep channels, longitudinal salinity structure (i.e. X2 position), horizontal stratification in Central Bay, semi-isolation of South Bay, and the interaction of shoals and channels with marshes and intertidal mud flats.

The work team provided a comprehensive list of ongoing monitoring and research activities (Appendix 6). A variety of new monitoring programs were also suggested: 1) bottom salinity/temperature sensors to accurately define X2 position; 2) deployment of various sensors to estimate fluxes (movements) of water and other materials at key points in the Bay-Delta system; 3) flow monitoring with a before and after monitoring design linked to CALFED actions and choice of the preferred alternative; 4) deployment of various sensors in selected shallow-water regions; 5) monitoring of deposition and resuspension of sediments; 6) periodic measurements of bathymetry; and 7) modeling.

The work team also provided a list of research needs to improve understanding of Bay-Delta hydrodynamics (Appendix 6). Stress was placed on specific issues important to improving the ability of models to confidently predict changes in hydrodynamics that might accompany CALFED actions. Topics included: 1) determining net transport through major cross-Delta connections (e.g. Georgiana Slough); 2) resolving the hydrodynamic basis and accuracy of the concepts supporting QWEST and carriage water; 3) determining dependence of water residence time on tidal and flow conditions in shallow water regions (e.g. Franks Tract); 4) quantifying the completeness of cross-sectional mixing in channels and the influence of size, shape, and connections with other channels; 5) research into all aspects of the hydrodynamics of shallow water areas, including processes within shallows and between shallows and deeper channels; 6) transport processes and flow structure in Suisun Bay and areas downstream; 7) fluxes of materials and organisms in areas of interest; 8) processes of sediment deposition and resuspension; and 9) numerical modeling.

The work team identified several possible indicators. The proposed calculations of fluxes of material and organisms at various points in the system might serve as indicators, especially the fluxes in waterways of high interest (e.g. Delta Cross Channel or various points in Old River). Inferred mass fluxes similar to QWEST or cross-Delta flow might be possible. Water level at the Golden Gate or X2 position could also serve as indicators.

Virtually all program elements in the Bay-Delta system are linked to hydrodynaimcs to some extent. The strongest links identified were to Fish-X2 relationships, shallow-water habitat and watersheds, contaminants (Water Quality Program), and system productivity at lower trophic levels.

System Productivity at Lower Trophic Levels -- This program element serves a dual purpose being part of both the Ecosystem Restoration Program and the Water Quality Program. The work team addressed a number of issues in their conceptual model and monitoring and research program including physical processes, primary production by phytoplankton and benthic plants, the microbial food web, zooplankton and macrozooplankton (mysid shrimp and amphipods), benthic macroinvertebrate communities, exotic species, variation in the relative importance of issues among geographic regions (Appendix 7).

The work team identified existing monitoring programs and provided a list of monitoring needs (see Appendix 7 for details). The work team began with a short list of general considerations that applied to several elements of the sampling program. The work team recommended: 1) establishment of continuous monitoring stations for physical and chemical variables in preference to, or supplemented by, shipboard monitoring; 2) continued use of conductivity-temperature-depth sensor packages with additional sensors as needed; 3) studies to determine the effects of alternative sampling frequencies and schemes with regard to daily and spring-neap tidal cycles; 4) development of a standard policy for storage and archiving of biological samples; 5) incorporation of new techniques of data acquisition and analysis as they prove their utility; and 6) the program must be designed to detect and track newly introduced species. Another general consideration not included in the list but implicit in much of the plan was that monitoring had to be extended into more shallow-water areas than are currently monitored by ongoing programs.

The list of monitoring needs was very detailed, presenting specific recommendations for variables to be monitored under more generic topics. The more general topics included: 1) basic physical variables ranging from precipitation to light attenuation in the water column; 2) flow variables; 3) chemical measurements including nutrients and organic carbon; 4) measures of biomass and primary production for phytoplankton, benthic algae, and submerged aquatic vegetation; 5) microbial communities; 6) zooplankton species composition, biomass, and production; 7) sediment quality; and 8) species composition, abundance, biomass, and size distributions of benthic macroinvertebrates. The work team also presented a list of 20 research topics and provided a detailed justification for each. The work team stressed that such research is needed to understand the ecosystem processes underlying ecosystem responses observed in the monitoring data.

The work team observed that most of the measurements suggested as part of the monitoring program would serve as lower-level indicators but that none of them would serve as a higher level indicator for measuring progress toward CALFED goals. Several of the variables were identified as possibly useful as intermediate-level indicators notably primary production and exogenous carbon input. Linkages were identified with Hydrodynamics, System Productivity of Fish/Invertebrates Fish-X2 Relationships, Contaminants (Water Quality Program), and the Research Program. The first two linkages were identified as the strongest. Although not identified by the work team, there was a strong implicit linkage to the Shallow-water Habitat and Watersheds elements.

Bay-Delta System Productivity at Upper Trophic Levels – This work team product addresses monitoring and research needs for the fishes and larger macroinvertebrates (i.e. crabs and crayfish) of the Bay-Delta system. Delta smelt and chinook salmon are mentioned in the plan but are addressed in more detail in single-species plans. The work team concentrated on three management goals to guide design of the monitoring and research program: 1) management of harvested populations; 2) monitoring of status and trends species; and 3) assessment of general trophic dynamics among estuarine species (Appendix 8).

The work team provided a detailed review of existing monitoring efforts. Most of the present monitoring activity is conducted through the Interagency Ecological Program (IEP). Proposed new sampling to supplement ongoing IEP sampling was presented in the context of the three management objectives.

Management of harvested species emphasized monitoring for striped bass, American shad, white and green sturgeon, various catfishes and Dungeness crab and crayfish. Additional monitoring for adult American shad was limited to measures of catch per unit effort derived from the recently initiated Central Valley and Anadromous Creel Survey. Collection and analysis of data on adult American shad captured as part of other trapping and netting programs should also be pursued. The work team suggested increasing tagging efforts for adult white sturgeon and increasing trawling efforts in the lower Sacramento River and Suisun Bay for juvenile white sturgeon. Green sturgeon are poorly sampled at all life stages, primarily because the population is small. The work team suggested the measurement of spawning success could possibly be monitored using fyke nets for young-of-the-year green sturgeon at the Red Bluff Diversion Dam on the Sacramento River. Egg and larval sampling was also suggested as possible methods in the upper Sacramento River and Feather River. The only new monitoring suggested for striped bass was to increase effort in shallow water areas to better understand juvenile habitat use.

Monitoring of status and trends species is intended to provide data on common species "representative" of groups of species rather than attempting to monitor all 165 species of fish that have been captured from the Bay-Delta system. Many of these species are already monitored adequately by existing programs. The species that were not adequately sampled because of habitat preferences or gear efficiencies could be divided into three groups. The first group includes species that mainly use the Bay-Delta as large-sized juveniles or adults. Monitoring of these species could be improved by expansion of existing programs utilizing gill nets and trammel nets and recording data for all species captured rather than just program target species (e.g. striped bass). Addition new elements could include an index of fish health and a creel census. The second group of species includes species using rocks, pilings, and other structure as habitat. Monitoring of these species will require selection of appropriate methods such as baited traps, bait angling, or creel census. The third group includes species using habitats not sampled by present programs. For example, there is no sampling for fish occupying "intermediate depths" between shallow-water channel edges and deeper-water midchannel stations. New monitoring would involved adaptation of existing programs or design of new programs to sample these areas.

To address assessment of food chain dynamics, the work team identified sampling on the basis of three salinity regimes or regions and the species expected in each one. The regions were the Delta, brackish waters, and polyhaline waters. Monitoring would include diet studies for poorly understood species and monitoring of contaminant body burdens to examine bioaccumulation of contaminants through the food chain.

The work team provided detailed descriptions of needed research. The research was categorized into four broad categories: 1) studies to improve the suggested monitoring program; 2) studies to develop new monitoring indicators; 3) studies to provide baseline data and methods that will be useful in detecting and assessing the effects of new introductions; and 4) studies to analyze and interpret data collected by the monitoring program.

The work team identified the various measures of abundance, distribution, contaminant body burdens and diets as possible indicators. The research studies also identify the need for additional measurements on topics such as physiological condition that might serve as lower level indicators.

The work team identified links to several other ERP elements including River Resident Fishes, Bay-Delta Shallow-water Habitat and Watersheds, and Delta Smelt. The work team also recognized a link to the Water Quality Program based on the contaminants aspects of the proposed plan.

Fish-X2 Relationships -- The X2 standard is currently an important regulatory tool in the Bay-Delta system. The X2 standard is based on correlative relationships, derived from existing data, between X2 position and abundances of some estuarine species. There is not complete scientific consensus regarding the usefulness of the X2 standard for managing the Delta. The major factor leading to lack of consensus is that the underlying ecological processes have not been elucidated. Presumably with some understanding of the underlying cause and effect relationships encompassed in X2, more direct management actions might be possible for some species. These more direct management actions might result in lower water costs relative to the present X2 standard. Given the great importance of these issues in guiding management decisions, a small work team was formed to design a research program to elucidate the causes of the Fish-X2 relationships (Appendix 9).

The work team provided a detailed justification for the research program, a detailed conceptual model, and a research plan including 30 possible studies. The work team was careful to design an integrated research program rather than simply listing a series of research studies. The program was designed so that a number of the 30 total studies would or would not be conducted depending on the results of earlier studies in the program. The work team indicated that many of the specific research proposals required similar approaches and suggested that the research program be organized around a common framework including consistent approaches for topics including data analysis, hydrodynamic modeling, and population monitoring. Hydrodynamic and population monitoring were also recurring themes. The list of individual research projects is too detailed to summarize but the studies were organized around a series of seven general issues that are the basis of the conceptual model: 1) variation in the physical environment with X2 position; 2) variation in the retention and recruitment of organisms with gravitational and lateral circulation; 3) variation in the retention and recruitment of organisms with circulation patterns in the low salinity zone; 4) variation in the extent or quality of physical habitat with X2 position; 5) variation in food supply with X2 position; 6) variation in entrainment effects with X2 position; and 7) effects of X2 position distinguishable by comparative studies of delta smelt and longfin smelt ecology. The final smelt element of the program focuses on two species with similar life histories but which appear to relate to X2 in very different ways.

Because this is primarily a research program, there were no indicators identified. Because this element represents a highly technical, interdisciplinary, and integrated study design, the work team suggested a number of institutional considerations for the organization and management of the program (see Appendix 9 for details). The intent of the suggestions is, at least in part, to assure the scientific integrity of the research program, assure a long-term commitment of the research team, and maintain close communication with the adaptive management process. These suggestions will have to be reconciled with the CMARP recommendations for institutional structure (Chapter VII) as development of CMARP proceeds. This element is closely linked with most of the other Bay-Delta monitoring elements including Hydrodynamics, Delta Smelt, Upper and Lower Trophic Level System Productivity, Bay-Delta Shallow-water Habitat and Watersheds, Data Management, Focused Research Program, and Institutional Structure.

Delta Smelt -- Similar to X2, the status of delta smelt and the response of the population to management actions are of high interest in the Bay-Delta system. Given the high level of interest, a small work team was assembled to address monitoring and research needs for delta smelt (Appendix 10).

The work team provided a conceptual model based on current knowledge and highlighting hypotheses to test to clarify critical aspects of delta smelt life history. The work team summarized the existing monitoring programs most of which are conducted by IEP. The work team identified several topic areas where additional monitoring is needed, including improved monitoring and delineation of spawning habitat and additional larval monitoring in the Delta and Suisun Bay. The proposed research program included four general areas of emphasis including studies of basic biology and physiology, habitat extent and quality, growth and condition, and an integrated monitoring effort of transport and recruitment processes.

The work team suggested that comparative statistics derived from delta smelt abundance and distribution indices might serve as a useful indicator of the performance of CALFED management actions. Given the high interest about delta smelt, such an indicator might be useful at a variety of levels. This element is closely linked to the Fish-X2 Relationships, especially the comparative delta smelt and longfin smelt study proposed in that element. Other linkages are the same as for Fish-X2 Relationships.

Bay-Delta Shallow-water Habitats and Watersheds -- Restoration or rehabilitation of Bay-Delta shallow-water habitats is a major component of the ERP as presently envisioned. Given the importance of these management actions to the CALFED program, a strong monitoring and research element is required. This component is very similar to the River Fluvial Geomorphology and Riparian Issues group because, although the general concepts of shallow-water ecosystem function are recognized, the outcomes of specific actions are still difficult to predict. An additional layer of uncertainty is added when benefits to specific species are expected because the importance of shallow-water habitats to many native species has not been established.

The work team presented conceptual models that emphasized the processes important to the maintenance of tidal flat and tidal marsh habitats (Appendix 11). Emphasis was placed on the interaction of physical and ecological processes. A separate discussion of diked marshlands was also provided.

The work team presented a monitoring scheme based on standardized project level monitoring and comparisons of results with data from reference (least-disturbed) sites. A six step outline for developing project designs and monitoring programs was presented. The six steps included: 1) set qualitative project goals; 2) develop a conceptual design for the project; 3) select performance indicators and monitoring elements; 4) select stressor indicators and monitoring elements; 5) identify reference conditions and reference sites; 6) design the project-specific monitoring program. The work team then provided a list of candidate indicators and the monitoring elements required to evaluate each indicator. Proposed indicators include wetland integrity, shoreline change, channel morphology, wetland hydrology, tidal elevation, patchiness, sediment characteristics, water quality, target population status, community structure, and human activity (See Appendix 11) for details. Target population status includes special status species identified by CALFED or other agencies. Assessment of community structure includes plants, invertebrates, fish, birds, and small mammals. The work team did not recommend specific methods for monitoring but presumably there will be a mixture of methods used similar to the recommendations of the River Fluvial Geomorphology and Riparian Issues group. A separate element for Bay-Delta Shallow-water Fishes (Appendix 12) was submitted as a stand-alone product.

A number of research needs were listed. The research needs were derived from CALFED documents, other CMARP work team products and other existing programs in the Bay-Delta region, including the Bay Area Wetlands Ecosystem Goals Project and the Research Recommendations for the Regional Monitoring Strategy. General topics were avian resources, fish resources (see Bay-Delta Shallow-water Fishes below), small mammals, marsh physical processes, and various needs for implementing and understanding marsh restoration.

The work team identified linkages with a number of agencies and ongoing programs including IEP, U.S. Fish and Wildlife Service, California Department of Fish and Game, Point Reyes Bird Observatory, San Francisco Bay Bird Observatory, and the Bay Area Regional Monitoring Program. Though not explicitly identified, there were implicit linkages to other ERP monitoring elements and CALFED Programs including River Fluvial Geomorphology and Riparian Issues, Hydrodynamics, Bay-Delta Shallow-water Fishes, System Productivity at both Lower and Upper Trophic Levels, and the Water Quality Program particularly in regard to contaminants.

Bay-Delta Shallow-water Fishes – As noted for the previous monitoring element, restoration of shallow-water habitats in the Bay-Delta region will be a major component of ERP. It is generally assumed that such restoration will result in increased populations of desired fish species; however, supporting evidence for this assumption in the Sacramento-San Joaquin estuary is sparse.

The work team presents a brief conceptual model that incorporates several important ideas (Appendix 12). Although most resident and migratory species of the Bay-Delta system can be found in shallow-water habitats at some time in their life cycle, such habitats are not necessarily of special importance to maintenance of the population. For other species, shallow-water habitats may be essential for completing all or part of the life cycle. The ecological function of shallow-water habitat will vary among species. Important functions of shallow-water habitat could include spawning habitat, refuge from predators, and near-shore migration corridors. Habitat use by fishes may vary seasonally and annually.

The work team identified two ongoing IEP programs as providing important data for this monitoring element, the U.S. Fish and Wildlife beach seine survey and the California Department of Fish and Game electrofishing survey. These programs were thought to provide sufficient coverage of the Delta, though some expansion of both surveys was suggested. Project specific monitoring was briefly discussed and a monitoring scheme similar to the one described in the previous element was suggested. As above, an emphasis was placed on pre- and post-project monitoring data and comparison of project results with results from non-project sites. Suggested variables to be monitored included presence/absence of species, relative abundance of common species, diet, and physiological variables ranging from condition factor to contaminant body burdens. The work team also suggested monitoring of the distribution and abundance of shallow water habitat types similar to that suggested by the Bay-Delta Shallow-water Habitat group and Watersheds group.

The work team recommended two areas of research be prioritized (Appendix 13). First, additional research concerning appropriate sampling methods for shallow-water habitats needs to be pursued. Second, key questions regarding use of shallow-water habitats by various species of fish need to be resolve. Sampling issues are presently being addressed by several IEP sponsored studies and may be at least partially resolved in the near future. Most of the fish-use aspects are not presently being studied.

The work team did not attempt to identify indicators; however, several were suggested in the Bay-Delta Shallow-water Habitats and Watersheds plan. The work team did identify linkages to a number of other ERP elements including Bay-Delta Shallow-water Habitats and Watersheds, Bay-Delta System Productivity for Upper Trophic Levels, River Resident Fishes, and Delta Smelt.

Chinook salmon – The separation of the Bay-Delta system and river system chinook salmon monitoring plans is artificial and was required by the organization of the report. In reality, these two portions of the plan will be tightly integrated into a single life-history based plan across all habitats. The Bay-Delta salmon work team provided a narrative conceptual model based on research and monitoring completed to date (Appendix 13).

The suggested monitoring program stressed existing monitoring programs for juvenile abundance, distribution, and survival conducted as part of CAMP, IEP, and other agency activities. The work team did suggest new monitoring consisting of sampling of migrating juveniles as they exit San Francisco Bay. In addition, the work team suggested that existing studies of survival using coded-wire-tagged hatchery fish be supplemented with similar studies using tagged wild fish if possible. The work team also suggested monitoring of physical parameters including water quality and hydrodynamics in conjunction with the salmon studies. Similarly, the work team suggested monitoring of prey availability and fish community assemblages. All of these additional monitoring elements have been identified in previously described monitoring elements.

The work team provided a detailed list of research topics and also prioritized them (see Appendix 13 for details). Five high priority areas of research were identified. First, the importance of various types of lower river and Delta habitat in various salmon life history strategies and juvenile survival needs to be evaluated. Second, determine the causes of lower survival in the Central Delta compared to the mainstem Sacramento River. Third, assess various methodologies for determining race, basin or hatchery origin, and age structure. Also, assess new techniques for indexing the abundance and survival of juvenile salmonids. Implement the improved methods. Fourth, identify the influences of hydrodynamics on the survival and abundance of juvenile salmonids. Fifth, determine if food is limiting the survival of juvenile salmonids in the Delta. An additional ten lower priority issues were also identified.

The work team did not suggest specific indicators but suggested that the various measures of abundance and survival might serve an indicator function. Linkages to other monitoring elements were not explicitly mentioned but the list of monitoring and research topics suggested links with all elements of the Bay-Delta system except Delta Smelt and Fish-X2 relationships. Linkages to the Water Quality program were also implied.

Steelhead -- The river phase of the steelhead life history was addressed above under River Systems. The work team also addressed the Bay-Delta phase of the steelhead life cycle (Appendix 5). As already noted, the work team identified existing anadromous salmonid monitoring programs and indicated their usefulness for monitoring steelhead. New monitoring and research elements suggested for the Bay-Delta relate to evaluation of Bay-Delta water operations on steelhead emigration and rearing. Specific needs mentioned included determination of the timing of smolt emigration through the Delta, magnitude of diversion of smolts into the South Delta and entrainment at the pumping facilities, and the effect of the loss of estuary rearing habitat

Monitoring for Nonindigenous Organisms -- This monitoring element primarily addresses the Bay-Delta ecosystem, generally acknowledged to be one of the most intensely invaded ecosystems in the world. The work team provides a justification for the need for a separate monitoring component for nonindigenous species rather than depending on the general monitoring programs already discussed above (Appendix 14). Three fundamental objectives were identified for the monitoring program: 1) detect new introductions; 2) monitor the spread of recent introductions; 3) identify and assess mechanisms of introductions. Two closely linked research purposes were understanding how introduced organisms affect the ecosystem and understanding the different factors that affect the success or failure of introductions.

The work team identified three elements necessary in the monitoring program to meet the general objectives (see Appendix 14 for details). First, sampling must include appropriate habitats, meaning habitats where introduced species are commonly first detected. A related point is that existing monitoring programs must collect, identify, and report new species. Second, organisms must be recognized as new introductions. This is an important problem for small organisms such as invertebrates and algae. Third, a system to ensure accurate and timely identification of suspected exotic species is needed.

The work team did not identify specific indicators for this monitoring element. Although not explicitly identified, this monitoring element links to all other monitoring elements to involve collection of organisms. All monitoring programs should have procedures in place to identify and report suspected new exotic species.

Research Needs

The research needs identified for each monitoring element have already been summarized in the individual element sections (see Appendices 1-14 for details). The needs identified are extensive. In some cases, the work teams have been very specific about what studies should be conducted. In other cases, the recommendations were very general. This difference is directly related to the existing level of knowledge. Work teams addressing topics with existing (or recently completed) monitoring and research programs presented specific and focused research proposals. Work teams addressing topics relatively unstudied in the Sacramento-San Joaquin system were more likely to present general topics for research. The extensive nature of the research recommendations also results from the CALFED objective to understand ecological processes to aid in adaptive management. General monitoring is generally inadequate to develop understanding of process. Manipulative experiments or detailed study of natural situations are needed to meet the objective. Given the long list and potentially high cost of the research elements recommended, it is highly likely that CALFED will have to prioritize the research elements. Such a prioritization must strike a careful balance between the two levels of research and also consider the importance of each topic to meeting CALFED goals and objectives.

Linkages

Linkages among the various ERP program elements have been addressed within each element as have some of the linkages with other program elements; however, there are many additional linkages that were not identified explicitly by the work teams. Linkages of ERP CMARP elements with elements of the Water Quality Program were the most commonly identified. These linkages stressed contaminants and general water quality measures important to organisms such as salinity. It was also recognized that bioassessments of fishes, invertebrates, and algae can be useful for both ecosystem and water quality monitoring.

Linkages of the riverine components of ERP CMARP with the Watershed Program were commonly recognized. Conceptual models that did or could be extended into the upper watersheds were presented by several work teams. From an ecological perspective the boundary between ERP and the Watershed Program is completely artificial and it is possible that the boundary will blur in some cases, when CMARP is implemented.

One important linkage that was not explicitly recognized by all of the work teams was the linkage between ERP CMARP and the monitoring of special-status species that were identified by the Conservation Strategy and subsequently incorporated into the ERP. Clearly, all monitoring and research components will have to be designed to integrate general community monitoring and special-status species monitoring to the greatest extent possible. It is likely that some focused special-status species monitoring will be required.

The Water Transfers Program has potential ecological effects depending on the tools used. In-channel conveyance and diversion have implications for stream flow that may have to be addressed by ERP CMARP. Less obvious are potential effects of conjunctive use of groundwater on ecosystems. Because groundwater and surface water are dynamically linked, groundwater withdrawals can have direct effects on stream flow of nearby streams and water levels in wetlands. The quality of groundwater entering these systems may also be important to ecological functions. The effects of ERP actions on water must be monitored. For example, assessments of evapotranspiration rates of restored wetlands and riparian forest might be necessary to understand effects of ERP actions on water transfers and water use efficiency. Possible effects on water quality for urban use of increased organic carbon loading from restored wetlands are also potentially important. There are also linkages between ERP and the Levees Program, through the Levee Habitat Mitigation Monitoring Plan

(Levees Report, Appendix E). Levees provide both terrestrial and instream habitat. Construction and maintenance activities to ensure levee integrity will be assessed for site specific and cumulative effects on the biological communities that are associated with them.

Linkages will also be necessary between ERP CMARP and the Strategic Plan for the Ecosystem Restoration Program (Strategic Plan), if ERP adopts the Strategic Plan wholly or in part. The Strategic Plan identifies 12 important issues and opportunities to consider in developing an adaptive management program, all of which will require monitoring and research. The issues are: 1) introduced species; 2) natural flow regimes; 3) channel dynamics, sediment transport, and riparian vegetation; 4) flood management as an ecosystem tool; 5) flood bypasses as habitat; 6) shallow-water habitats; 7) contaminants; 8) limiting factors; 9)X2 relationships; 10) decline in Bay-Delta system productivity; 11) entrainment of fish at pumps; and 12) the importance of the Delta for chinook salmon. All but the entrainment issue are directly addressed by one or more ERP CMARP or Water Quality Program elements. Entrainment issues are mentioned in a number of CMARP Bay-Delta system work team products. Programs directly focused on entrainment issues (at least at the State and Federal facilities) will likely arise when the preferred alternative is selected and as part of real-time monitoring programs designed to guide project operations.

Perhaps the most important potential linkage between the ERP and other Programs is the selection of a preferred alternative and the choice of storage and conveyance tools chosen to implement the alternative. Many of the monitoring and research programs will have to be tailored to assess the success and effects of those choices. For example, reconfiguration of Delta channels to provide protection for fish species will have to be assessed to determine if those benefits are realized. The monitoring and research elements summarized above should not be viewed as static. The elements of ERP CMARP should continue to evolve to best meet CALFED needs as those needs are clarified.

Chapter V, part C. Water Quality

1. CALFED Program Goals and Objectives

The CALFED Bay-Delta Program's goal for water quality is to provide good water quality for environmental, agricultural, drinking water, industrial, and recreational beneficial uses. Because water quality is intrinsically linked to ecosystem health, this section of the monitoring plan also addresses the CALFED Ecosystem Restoration goal of rehabilitating the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities. The CALFED watershed program goal, to help coordinate and integrate existing and future local watershed programs and to provide technical assistance and funding for watershed activities, will be partially addressed by the water-quality-monitoring program.

The water-quality-monitoring program scope includes baseline, trend, effectiveness, compliance/mitigation and operations monitoring. The program addresses the programmatic water quality actions outlined in the CALFED Phase II Report (November 1998, see Table 1).

Table 1. Water Quality Program Actions

Drinking Water	Increase source-water quality and treatment technology to reduce potentially toxic and carcinogenic disinfection by-products by controlling TOC, pathogens, turbidity and bromides
Pesticides	Reduce impacts of pesticides through development and implementation of Best Management Practices, for both urban and agricultural uses, and support of pesticide studies and pilot projects for regulatory agencies while providing education and assistance in implementation of control strategies for the regulated pesticide users.
Organochlorine Pesticides	Reduce the load of organochlorine pesticides in the system, including residual DDT and Chlordane, by reducing runoff and erosion from agricultural lands through Best Management Practices. Sediment control will also protect valuable topsoil and prevent costly maintenance of drainage systems.
Trace Metals	Reduce impacts of trace metals such as copper, cadmium, and zinc in upper watershed areas, near abandoned mine sites. Reduce impacts of copper through urban stormwater programs and agricultural Best Management Practices. Study

	the ecological impacts of copper in the Delta. Determine the feasibility of copper reduction in the Delta.
Mercury	Reduce mercury in rivers and the estuary by source control at inactive and abandoned mine sites. Also study bioavailable mercury in the rivers and the estuary and its potential threat to human health.
Salinity	Reduce salinity through reduction of leaching of agricultural land via irrigation improvement, crop selection and changes in land use. Reduce imports of salt and study non-agricultural source contributions. Salinity reductions in the river would also incorporate real-time management of salt discharges. San Joaquin drainage problems have been evaluated in several studies over the past two decades. Complete resolution of the San Joaquin drainage problems is beyond the scope of the CALFED Bay-Delta Program.
Selenium	Reduce selenium, through irrigation control, crop selection, and possibly land fallowing or land retirement. Impacts of selenium will be further reduced by real-time management of selenium ladened agricultural drain water released to the San Joaquin River to minimize concentrations in the river when selenium discharges occur.
Turbidity and Sedimentation	Reduce turbidity and sedimentation which affect several hydraulic areas in the Bay/Delta and its tributaries, including treatment of drinking water sources. Study ecological impacts of sedimentation. Control sedimentation in several watersheds to protect spawning beds and maintain capacity of streams.
Low Dissolved Oxygen	Reduce impairment of rivers and the estuary caused by substances that exert excessive demand on dissolved oxygen. Oxygen-depleting substances are found in waste discharges, agricultural discharges, urban stormwater, sediment, and algae.
Toxicity of Unknown Origin	Through research and monitoring, identify parameters of concern in the water and sediment within the Delta, Bay, Sacramento River and San Joaquin River regions and implement actions to reduce their toxicity to aquatic organisms.

II. Goals and objectives of the monitoring plan

The goal of the water-quality-monitoring plan is to monitor water quality and associated physical and environmental variables to document the effects of CALFED Stage 1 actions on water quality and on the ecosystem (Table 2). A monitoring network will be established to evaluate the success of proposed CALFED Water Quality Program Plan actions, to address or verify identified water-quality problems, and to assess trends, loads, and sources of important water quality constituents. The major question, Is Delta water quality improving?, will be answered with this monitoring program.

Table 2. Water Quality Monitoring Objectives

1. Assess effects of CALFED activities (including Ecosystem, Storage and Conveyance, Water Transfers, Water Use Efficiency, Watershed and Levee Programs) on water quality
2. Determine sources, loads, and trends of water-quality constituents of concern
3. Assess system productivity of Bay/Delta waters
4. Monitor water and sediment quality as necessary to comply with CALFED actions
5. Provide ongoing data on water-quality constituents of concern, such as bromide, that may serve as triggers for CALFED actions

Monitoring Principles

The water-quality-monitoring plan is based on several monitoring principles. To maximize the efficiency and effectiveness of monitoring, the monitoring plans are based on conceptual models (see Figure 1: Disinfection Byproduct Precursors, and Figure 2: San Joaquin Basin Dormant Spray Pesticides, for example). Also to maximize efficiency and effectiveness, the monitoring plan uses existing programs as much as possible (Table 3). For example, the proposed contaminant monitoring program is based the Sacramento Coordinated Monitoring Program, the USGS National Water Quality Assessment Program and special programs, the Interagency Ecological Program and the San Francisco Estuary Institute regional monitoring program. The water-quality-monitoring plan is integrated with monitoring plans for the other common programs (see Linkage section at the end of this chapter). To the extent possible, local cooperation and involvement is encouraged. The proposed program should be closely linked with monitoring efforts by local watershed groups.

II. Recommended Monitoring

Five work groups addressing different regional and constituent groups developed the recommended monitoring. The five groups are Sacramento Region, San Joaquin Region, Bay-Delta Region Contaminants, Bay-Delta Region Ecosystem Productivity, and Bay-Delta Region Drinking Water. Full reports from these work groups are in Appendices ___ through ____. The individual monitoring programs were integrated into the comprehensive program presented here. The water-quality-monitoring program is summarized for environmental contaminants, ecosystem productivity and drinking water.

1) Environmental Contaminants

Contaminant monitoring is designed to monitor both human health and ecosystem effects of contaminants. This monitoring would address the CALFED actions to improve aquatic environments by reducing the concentrations and loadings of contaminants. The contaminants monitored are based on lists of contaminants developed by the CALFED Water Quality Program, Regional Water Quality Control Boards, the U.S. Environmental Protection Agency and technical experts. These programs will be coordinated to provide information on the following classes of constituents:

- General water and sediment chemistry
- Nutrients
- Metals and trace elements
- Pesticides
- Turbidity and sedimentation
- Pathogens
- Water and sediment assays
- Bioaccumulation
- Ecological effects of contaminants

General Water and Sediment Chemistry
Measurements such as temperature, specific conductance or electrical conductivity (EC), salinity, pH, total dissolved solids, dissolved oxygen (DO) general indicators of water quality. Temperature and pH are critical in determining speciation of other water-quality constituents. This is important in determining fate of constituents and in some cases bioavailability or toxicity of contaminants. EC, a measure of salinity, is often related to other constituents and can serve as a surrogate for other measurements. Salinity measurements are important because salinity criteria need to be met in the Bay-Delta estuary, according to Bay-Delta water rights agreements. Sediment characteristics such as grain-size, total organic carbon (TOC), ammonia and sulfides are recommended to assess the condition of the sediment habitats.

Many of these general chemical measurements have ecosystem effects. Elevated temperatures and low dissolved oxygen levels may adversely affect migration and spawning of salmon and steelhead, for example.

Nutrients
Nutrient concentrations can indicate the potential for algal blooms, which can cause problems in drinking water taste and odor and for ecosystem effects such as eutrophication. Monitoring of nutrient concentrations is useful to determine possible sources of nonpoint-source pollution such as from agriculture, dairies and livestock operations and from urban runoff.

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Metals and Trace Elements
High concentrations of metals and trace elements can be toxic to humans and aquatic organisms. Some trace elements such as selenium, bioaccumulate and can pose a threat to wildlife even though dissolved selenium concentrations may be relatively low. Monitoring of metals and trace elements will focus on particular contaminants of concern in different watersheds. In the Sacramento watershed, metals such as mercury, cadmium, chromium, copper and zinc are released from abandoned mines, and mercury buried in hydraulic mining debris throughout the estuary, delta and watershed may be available for biological uptake. In the San Joaquin watershed, trace elements of most concern are selenium, boron and molybdenum. Monitoring and special studies in the Bay-Delta to identify sources and effects of mercury and selenium to the Bay-Delta are proposed.

Pesticides
Pesticides will be selected for monitoring based on the quantity of pesticide used in a particular location, the timing of application and the physical properties of the pesticide, which determine its fate and transport. Certain pesticides that are no longer used but are persistent in the environment (DDT, toxaphene, dieldrin and chlordane) are proposed for monitoring as well.

Turbidity and Sedimentation
Turbidity and sedimentation are of concern for contaminant, drinking water and ecosystem effects. Contaminants such as organochlorine pesticides, metals and other inorganic constituents, such as phosphorus, can be transported with sediments. Turbidity and sedimentation will be monitored to assess loadings of some of these contaminants, as they affect water quality and water treatment (see drinking water contaminants section). Ecosystem effects include smothering of spawning gravels and effects on ecosystem productivity, transport of contaminants and benthic effects.

Pathogens
Pathogens such as *Giardia* and *Cryptosprodium* are proposed for monitoring in both the Sacramento and San Joaquin watersheds. However, better analytical test methods are needed to assess the viability and actual human health risks associated with existing pathogen levels in the system. See the drinking water section for more detail.

Water and Sediment Bioassays
Water and sediment bioassays will be used to monitor toxicity to biological organisms. Toxicity monitoring is essential because toxicity may result from an unknown contaminant or from a combination of contaminants, that may not be detected by analysis of individual contaminant levels. Toxicity identification evaluations (TIEs) are proposed to analyze the source of detected toxicity.

Bioaccumulation
Bioaccumulation monitoring is essential to monitor ecosystem effects of contaminants that concentrate in the food chain. Bioaccumulation information may also be used to determine human health risks from ingestion of fish and shellfish. Resulting toxicity and

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ecosystem effects would not be detected by individual contaminant monitoring. Examples of bioaccumulation monitoring proposed are determining the bioaccumulation potential of sediment contaminants in bivalves such as *Potamocorbula*, fish tissue monitoring and selenium bioaccumulation studies.

Ecological Effects of Contaminants

Ecological effects of contaminants should be monitored in close coordination with restoration monitoring. Many ecological response indicators can be used to monitor contaminant effects. For example, the number of benthic species per sample is a commonly used indicator of benthic response to contaminants. However, in order to evaluate whether numbers of benthic species are affected by contaminanted sediments or other factors, a suite of "habitat" and "stressor" measurements must be monitored synoptically with the benthos. It is recommended that phytoplankton, zooplankton, benthic invertebrates, and several fish species be monitored as contaminant effects indicators. Measurements of production, growth, mortality, or reproductive capacity are also recommended.

Summary of Environmental Contaminant Monitoring

Environmental contaminants will be monitored for potential human health and ecosystem effects. This monitoring consists of the above general classes of contaminants, but will be focused spatially and temporally based upon existing information about these contaminants. For detailed information about specific monitoring proposed for each region and class of contaminants, see Appendices ___ through ____.

2) Ecosystem Productivity

In addition to monitoring environmental contaminants, the water-quality-monitoring program consists of monitoring to determine the biological productivity of the water and sediment. System productivity is a measure of ecosystem health. Ecosystem productivity monitoring includes monitoring of physical processes, conventional water quality (not including contaminants or human health effects), and the status of lower trophic levels (microbes, phytoplankton, aquatic plants, invertebrates not including decapod shrimp or crabs). The following general classes of variables are proposed for monitoring:

- Basic physical variables
- Flow variables
- Chemical measurements
- Primary producers
- Microbial communities
- Zooplankton
- Sediment quality
- Benthic fauna

Basic physical variables
This includes climate, meteorological measures, salinity, temperature, suspended sediment/water clarity, and light attenuation. These variables affect the biological productivity of the system. Salinity, temperature and water clarity will be monitored for both ecosystem contaminants (discussed in the previous section) and for ecosystem productivity.

Flow variables
Total daily inflow, diversion flows, tidal flows, and net (tidally-averaged) flows provide the essential underlying information defining the hydrologic environmental of the Bay-Delta and thus for interpreting and analyzing data from the estuary.

Chemical measurements
Dissolved oxygen, pH, nutrients, organic nutrients and organic carbon are essential to determine ecosystem productivity. Many of these constituents will be monitored for ecosystem productivity, environmental contaminant and drinking water purposes.

Primary producers
Primary producers are basic components of the food web, upon which the ecosystem depends. The biomass of phytoplankton is an indicator of the quantity of food energy (carbon) available to fuel the food web. Excessive phytoplankton biomass can suggest eutrophication. Primary production will be assessed by measuring the variables: phytoplankton biomass, phytoplankton primary production, phytoplankton species, benthic microalgae and submerged aquatic vegetation.

Microbial communities
Microbial communities, characterized by bacterial counts, biomass, and metabolic rate, are proposed for monitoring on a periodic, but infrequent basis, perhaps every quarter or in alternate years. Bacteria are an important part of the Bay's food web, but measurements are somewhat difficult and require specialized expertise.

Zooplankton
Zooplankton, a component in the food chain, will be assessed by monitoring: mesozooplankton, macrozooplankton, microzooplankton, gelatinous zooplankton and zooplankton secondary production. Assessing this step in the food chain is critical for ecosystem food-web analysis.

Sediment quality
Sediment quality is an important factor in assessing ecosystem health. Sediment contaminated with toxic substances may result in acute or chronic toxicity to benthic organisms and therefore affect ecosystem productivity. Sediment grain size, total organic carbon, total nitrogen, total sulfide, un-ionized ammonia and pH will be monitored.

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Benthic fauna

Benthic community composition can be used as an indicator of water quality and for documenting changes in lower trophic level aquatic community structure and secondary productivity. Several reasons justify this monitoring:

- Benthic fauna are an important trophic step between living and detrital particulate organic matter and higher trophic levels including fish, birds, and people
- Benthic fauna contribute to the flux of dissolved and particulate material (including contaminants) between the sediment and the overlying water
- The types and abundance of benthic animals and their variation are commonly used as indicators of water quality
- The benthos of coastal aquatic systems is particularly susceptible to invasions of exotic species released from ballast water. Because most benthic organisms do not move far after settlement, the benthic community provides a continuing record, through changes in species composition or abundance, of the effects of both short- and long-term changes in the environment.

Summary of System Productivity Monitoring

By monitoring water quality and the lowest levels of the ecosystem food chain, changes in the ecosystem as a result of CALFED actions can be analyzed. Many of the components of system productivity monitoring will also provide information to the other water-quality-monitoring program elements and to the ecosystem monitoring program.

DRINKING WATER

Nearly 23 million people are dependent on the Sacramento-San Joaquin Delta for their drinking water supply. There are public health issues associated with providing good quality water from the Delta (see Table 4). Disinfection by-products (DBPs) are produced when source water containing organic matter and bromide are disinfected in drinking-water-treatment facilities. DBPs could be reduced by reducing the amount of disinfectant used. However, reducing the amount of disinfection can result in greater quantities of disease-causing pathogens surviving the disinfection process. There are technological and cost limitations to treating pathogens and DBP precursors in drinking water. Therefore, it is critical that the Delta source water be closely monitored so that CALFED actions can be taken to produce the best quality source water possible.

Table 4. Drinking Water Contaminants and Potential Health Effects

Drinking Water Contaminant	Potential Health Effects
Pathogenic organisms	Infections; illness; possible deaths
Trihalomethanes (a DBP*)	Cancer; spontaneous abortions; liver; kidney, and nervous system toxicity
Bromate (a DBP)	Cancer

Water utilities using Delta water as a source of drinking water face significant challenges in meeting federal drinking water standards on DBPs due to much higher levels of DBP precursors in Delta water compared to the national averages. These utilities are able to meet current standards after considerable investment in drinking water treatment facilities.

Future drinking water regulations could become much more stringent if results from ongoing research indicate significant health risks of DBPs to humans. For example, the placeholder limits in Stage 2 of the Disinfectanct/DBP Rule, to be promulgated in 2002, would lower the Stage 1 limits on DBPs by 50%. In the immediate future, Stage 1 of the D/DBP Rule, to be promulgated in November 1998, would reduce the existing TTHM limits by 20% and impose a limit on the heretofore-unregulated DBP bromate. The new Stage 1 limit on bromate could be difficult to meet, especially during droughts when the bromide level in Delta water could be 10 or more times higher than that of the national average. Given the relatively few ozonation treatment plants using Delta water and their short histories of operation, it is too early to tell if the Stage 1 bromate limit could be met during drought conditions.

For the longer term, the potential combination of higher disinfection requirements and more stringent limits on DBPs could make it impossible for Delta agencies using existing advanced treatment processes (ozonation and chlroination with enhanced coagulation) to comply with future regulatory standards unless Delta water quality is significantly improved, especially during droughts.

TOC, bromide, and pathogenic organisms in Delta waters need to be controlled so that water utilities using Delta waters can meet current and new drinking water standards, and provide finished drinking water which will not cause adverse health effects.

However, CALFED actions may increase the concentration of constituents of concern in Delta waters. In particular, creation of wetlands as part of the CALFED Ecosystem Restoration program will likely increase the concentration of particular forms of TOC with a high propensity to form DBPs. Also, the increased tidal exchange resulting from the wetlands may increase the concentration of bromide and TDS in Delta waters. Due to impending regulation, bromide may serve as a trigger for CALFED action.

Drainage on Delta islands will increase as peat islands continue to subside, thereby increasing the loads of DBP precursors (DBPPs) pumped off island. Therefore, if subsidence mitigation is not a CALFED priority, DBPP loads associated with continued subsidence will continue to increase.

The key drinking-water-constituents of concern to be monitored are DBP precursor sources, concentrations and loads (TOC and bromide), pathogenic organisms (*Giardia*, *Cryptosporidium*, coliform bacteria, and viruses), the concentration of other chemical contaminants (pesticides, metals, and other organic compounds such as MTBE), TDS or salinity, nutrients, and turbidity (Table 4).

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Table 4. Drinking Water Constituents of Concern

Monitoring Constituent	Significance to Drinking Water Quality
TOC (DBP precursor)	Formation of disinfection byproducts
Bromide (DBP precursor)	Formation of brominated disinfection byproducts
Pathogenic organisms	Waterborne diseases
Chemical contaminants	Regulated drinking water-quality constituents
TDS or salinity	Taste and odor problems (salty taste), corrosion of infrastructure and appliances, effects on wastewater reclamation programs, groundwater conjunctive use programs and blending projects, health concerns (sodium)
Nutrients	Taste and odor problems (algae-geosmin and 2-methylisoborneol), effects on filtration (algae)
Turbidity	Effects on filtration and disinfection

Summary of Drinking Water-Monitoring

CALFED actions may significantly increase the concentration of drinking water contaminants in Delta waters, thereby exacerbating existing problematic conditions, particularly in relation to formation of DBPs. CMARP activities will monitor changes in contaminant concentrations to ensure water quality is not further degraded as a result of CALFED actions. Drinking water-quality contaminants are undergoing increasingly stringent regulation. Further degradation of Delta source waters increases the cost and decreases the effectiveness of water treatment.

Research Needs

Research needs for environmental contaminants, agricultural contaminants and drinking water contaminants are listed below. For detailed lists of research questions, see Appendices __ through ____.

1) Environmental Contaminants
   - Determine causes of unknown water and sediment toxicity
   - Develop toxicity testing with resident organisms
   - Develop contaminant effects indicators in the estuary.
   - Study bioaccumulation of contaminants
   - Determine sources of mercury and other contaminants
   - Determine fate and transport of mercury, selenium and other contaminants
   - Estimate sediment loadings and predict changes in sediment loadings due to CALFED actions including ecosystem restoration projects and changes in storage and conveyance
   - Research methods to manage urban stormwater drainage/urban runoff to minimize toxicity

- Research methods of control of introduced aquatic weeds/species that minimize toxicity to nontarget organisms
- Develop Best Management Practices to reduce the transport of pesticides and other contaminants to water sources

2) System Productivity
   - Reevaluate the flow-X2 relationship and update it (base the relationship on a larger dataset and make any changes in the relationship necessary)
   - Develop carbon and nutrient budgets for the estuary and its sub-regions
   - Develop models of phytoplankton dynamics for the estuary and its sub-regions
   - Determine the relative importance of various organic carbon sources in the northern estuary
   - Determine the fate of bacterial production in the northern estuary
   - Continue and expand work on retention mechanisms in the Low-Salinity Zone and seaward
   - Assess the role of benthic microalgae in the estuarine food web
   - Model studies of the food web
   - Study of the role in the food web of introduced zooplankton species
   - Continue studies of the influence of *Potamocorbula amurensis* on estuarine food webs
   - Anticipate the role in the food web of additional introductions of exotic species
   - Determine the roles of benthic invertebrates and various size classes of zooplankton in the food web leading to species targeted for restoration
   - Sediment studies to estimate loadings of sediment from the mainstem rivers into the Bay and Delta
   - Sediment studies to determine deposition rates, residence times, and burial rates for sediment in representative habitat types in the Bay-Delta
   - Determine benthic production in each major habitat
   - Determine the effects of shallow water restoration projects on primary production
   - Determine the importance of sediment and nutrients to production of phytoplankton and aquatic plants
   - Determine factors that control higher aquatic plant growth in the estuary

Drinking Water
- Determine how CALFED programs such as Ecosystem Restoration will affect the propensity of Delta waters to form disinfection byproducts (DBPs) when treated.
- Determine the effect of operational changes (such as reservoir reoperations, flow barriers, exports) on delivered water quality
- Determine loads of DBP precursors (DBPPs) produced by CALFED programs such as Ecosystem Restoration.
- Identify the key sources of DBPPs.

- Determine loads of DBPPs associated with key sources (e.g. agricultural and island drainage).
- Develop models and other tools to assess and predict the effects of CALFED programs on concentrations of DBPPs (including bromide) reaching major drinking-water intakes in the Delta.
- Identify source control measures for mitigation of pathogen and DBPPs
- Develop accurate predictive models of pathogen and DBPP behavior and transport.
- Identify methods for accurate determination of pathogens.
- Perform and evaluate pilot scale implementations of source control measures.

I. LINKAGES AMONG COMMON PROGRAM ELEMENTS

<u>Ecosystem Restoration</u>
The following is a partial list of monitoring common to both the water quality and ecosystem programs.

- Benthic invertebrates species composition and health can be an indicator of ecosystem health and therefore provide information on contaminants, introduction of exotic species, and productivity of the ecosystem.
- X-2 or salinity monitoring is important both for the ecosystem and water quality effects.
- The potential water quality effects of ecosystem restoration activities such as the creation of shallow-water habitat, setting back levees and/or the flooding of peat islands will be monitored.
- Measurements of the productivity of the ecosystem include monitoring such variables as microbial communities, sediment quality, benthic fauna, light attenuation, salinity and temperature.
- Exotic species affect both the ecosystem and water quality.

Water quality is an integral part of ecosystem health. The productivity of the ecosystem depends on such factors as temperature, salinity, nutrient concentrations and dissolved oxygen. Aquatic and sediment toxicity monitoring provide information both on water quality and ecosystem effects. The measurement of contaminant effects on fish reveals the presence of contaminants in the water as well as the resultant effects on fish. Water-quality investigations in the upper tributaries will be linked with other ecosystem measurements such as aquatic life, riparian vegetation, etc.

<u>Delta Levees and Storage and Conveyance</u>
Water and sediment quality monitoring is important for obtaining water-quality permits for levee maintenance and dredging operations. In turn, dredging and levee building operations need to be closely coordinated with water-quality monitoring. Monitoring of sediment (described in the ecosystem section of this report) provides information on water quality, levee erosion, channel scouring and sedimentation. Mitigation and levee enhancement restoration work required for levee repair work will be closely linked with water quality and the ecosystem programs.

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Water Transfers and Water Use Efficiency

Ground and surface water-quality monitoring will be integrated with the water transfers and water use efficiency programs. The quality of water (salinity and concentrations of contaminants such as selenium) will limit water transfers and the reuse of water. Also, measurements of water quantity (both groundwater and surface water) are important for both the water transfers and water use efficiency programs as well as calculations of loading of contaminants for the water-quality program.

Watershed

Water-quality monitoring in the upper tributaries (above dams) will be coordinated with the watershed common program. The watershed program will involve local resources and will conduct restoration activities in the upper watershed that may affect downstream water quality. Water quality monitoring will provide information on watershed function and human activities, (*e.g.,* source contaminants) and will be closely coordinated with monitoring of ecosystem attributes (*i.e.,* vegetation, fish, invertebrate species).

Table __. Major Existing Water Quality Monitoring Programs

Program Name	Region	Constituents Monitored								
		General	Metals	Nutrients	Organics	Sediment	Pesticides	Pathogens	Biological	Toxicity
California Department of Fish and Game	Sac.						X		X	
Department of Pesticide Regulation	Sac./San Joaquin						X			X
Compliance Monitoring, DWR	Bay-Delta	X		X						
Municipal Water Quality Investigations Program, DWR	Bay/Delta	X	X	X	X		X	X		
State Water Project Water Quality Monitoring Program, DWR	Bay-Delta	X		X	X			X		
Interagency Ecological program	Bay/Delta	X	X	X			X		X	
Central Valley Ambient Monitoring Studies/RWQCB	Sac./San Joaquin		X							X
San Francisco Estuary Regional Monitoring Program, SF Estuary Institute	Bay-Delta	X	X	X	X	X	X		X	X
National Water Quality Assessment Program, United States Geological Survey	Sac./San Joaquin	X	X	X	X		X		X	
Sacramento Coordinated Water Quality Monitoring Program/SRCSD, City of Sac., Sac. Co. Water Agency	Sac.	X	X		X		X	X		
Toxic Substance Hydrology Project, USGS	Bay-Delta						X			

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Chapter V, part D. DELTA LEVEE SYSTEM INTEGRITY

1. MONITORING OBJECTIVES

The fundamental objective of the overall Delta Levee System Integrity Program is to "reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees." The specific elements of the Delta Levee System Integrity Program are discussed fully in the CALFED long-term Levee Protection Plan and include:

1. Base Level Protection Plan:
   Target – Improve and maintain Delta levees to the PL 84-99 standard.
2. Special Improvement Projects:
   Target - Improve and maintain levees at key Delta locations to a level commensurate with the benefits protected.
3. Subsidence Control Plan:
   Target – Reduce or eliminate risk to levee integrity from subsidence.
4. Emergency Management and Response Plan:
   Target – Enhance existing emergency management and response capabilities in order to protect critical Delta resources in the event of a disaster.
5. Seismic Risk Assessment:
   Target – Identify risk to Delta levees from seismic events and develop recommendations to reduce levee vulnerability and improve their seismic stability.

The monitoring elements selected by the CMARP Levees Technical Team will support a determination of whether the above program elements are achieved.

Indicators have been identified for each of the program elements. An indicator is a set of system attributes that collectively provides a convenient way to evaluate the status of the overall system. Indicators will be used to show progress towards the CALFED Levee Program goals. For example, the indicator for the Base Level Protection Plan element, "number of levee miles at the PL84-99 standard," will be determined by a compilation of cross-section, inspection, and other data, and this determination will be used to measure progress towards the Base Level Protection Plan goal of improving the Delta levees to the PL84-99 standard.

Additionally, monitoring elements must be developed to insure that environmental mitigation is successful for effects from implementation of any of the above elements.

Levee Monitoring Objectives that Contain Physical Properties

1. Establish that a base level of flood protection for Delta levees at the PL 84-99 standard, or higher as necessary, has been achieved and maintained.
2. Establish that special levee improvements have been achieved and maintained in key Delta locations to a level commensurate with the benefits of levee protection.

3. Establish that the risk to levee stability from subsidence has been reduced.
4. Establish that an emergency management and response plan with the capability to protect critical Delta resources in the event of a disaster has been adopted and maintained.
5. Quantify Delta levee seismic risk and compare it to other failure modes.

<u>Levee Monitoring Objectives that Contain Biological Properties</u>
Establish that effects from any construction/management action associated with achieving the overall objectives of the Delta Levee System Integrity Program are mitigated as appropriate. Construction/management actions include:

A. Levee improvements or maintenance
B. Excavation of material at borrow sites and its transport to the construction sites
C. Channel dredging for fill material
D. Placement of dredge reuse material

II. CONCEPTUAL MODEL AND/OR LISTING OF HYPOTHESES AND ASSUMPTIONS OF THE SYSTEM

<u>Common Survey Standards</u>:
Monitoring plans for Delta Levee System Integrity Program elements are directly or indirectly dependent on accurate vertical and horizontal data. A common coordinate system for quantifying and mapping features that are tied to vertical and horizontal position in the Delta is critical in determining levee standard compliance, and the effects of subsidence and seismic activity. Specifically, minimum survey-control standards are needed to develop a network of vertical and horizontal control points in the Delta.

Without this common survey standard, true elevations and horizontal positions for Delta levees cannot be known, thereby leading to a false sense of confidence in survey data and flood protection. Appendix F contains specific recommended methodology for establishing the needed common survey standards for the Delta.

<u>Models and Assumptions of the Levee System</u>:
The Delta Levees component of CMARP does not have a classic, analytical model levee condition or behavior. However, several specific factors can be measured relative to each of the five Delta Levee System Integrity Program elements.

1. <u>Base Level Protection Plan and Special Improvement Projects</u>
   Levees may be built to various standards, depending on the level of flood protection desired. It is the goal of the Long-Term Levee Protection Plan to eventually implement Public Law 84-99 (PL 84-99) performance criteria for non-project levees in the Delta (See Attachment A to Appendix A). It is envisioned that higher flood protection standards may be desirable at key Delta locations to a level commensurate with the benefits protected. Most Federal project levees in the Delta already meet the PL 84-99 standard. PL 84-99 criteria include specific cross-section dimensions that must be achieved and maintained. The geometry of the levee will

significantly influence how the levee responds to geotechnical and hydraulic forces in the system.

Once a levee is built to a desired standard for flood protection, it is imperative that it be maintained to resist the many forces that work to undermine its integrity. The first step in levee maintenance is levee inspection, which detects various levee problems before they become critical threats. Levee inspections evaluate the condition of the levee crown road, the condition and inspectability of the land and water sides of the levee, the presence of levee encroachments and evidence of animal burrowing damage. Once a problem is detected with any part of the levee, maintenance should proceed. Appendix A describes the specific monitoring plan for these elements. (In some cases, the Special Improvement Projects element may include monitoring from other elements such as the Subsidence Control element.)

2. Subsidence Control Plan
Subsidence has substantially contributed to the Delta islands current condition of relatively tall levees protecting interiors below sea level. Recently, however, the risk to levee integrity from subsidence has diminished. Land management and levee maintenance practices have improved, and subsidence rates have decreased. In addition, a zone of influence (ZOI) extends from the levee crest to some distance inland, beyond which subsidence will not affect levee integrity. Outside the ZOI, interior island subsidence will not affect levee stability. However, subsidence within the ZOI may potentially impact levee integrity. The ZOI for a reach of levee can be determined using site-specific data. The Subsidence Control element will include monitoring to determine if levee integrity may be compromised due to subsidence (Appendix B).

3. Emergency Management and Response Plan
Delta levees have a history of failure, bringing the devastating effects of flooding to various land uses. Many of these levees failed without warning and were not tied to a single stressful event (storm, etc.). Proper emergency response activities can be a cost-effective supplement for levee protection; however, they cannot substitute for a proper maintenance and repair program.

Delta levees protect approximately 527,300 acres of farmland, 67,000 acres of urban development, and 82,800 acres of native habitat. The Delta's channels and adjacent banks provide habitat for fish and wildlife, accommodate shipping, provide local water supply, protect infrastructure and convey water to over 20 million Californians. Most of the protected land is below sea level and therefore emergency response actions are unusually important and require prompt response and action. A levee failure can endanger public safety and inundate thousands of acres of farmland up to 20 feet in depth; it is a costly process to reclaim the island. Also, such an event can cause significant salinity intrusion degrading Delta habitat and impeding the operations of major State and Federal water delivery systems.

An effective emergency response system is critical to the long-term protection of the Delta. The emergency response system must be monitored to insure that it adapts as conditions and needs change in the Delta (Appendix C).

4. Seismic Risk Assessment
Earthquakes can cause levees to fail by slumping or liquefaction of underlying soils. To date, there have been no known Delta levee failures or island inundations as a result of seismic events. However, several active faults are located sufficiently close to the Delta to present a threat to Delta levees.

In 1992, The Department of Water Resources, Division of Engineering completed the "Phase I Report, Seismic Stability Evaluation of the Sacramento-San Joaquin Delta Levees." Subsequently, the Department took several actions to reduce some of the unknowns that influence the evaluation of levee stability during earthquake shaking.

Assessments by the U.S. Geological Survey concluded that there is a high probability that a large magnitude earthquake will occur in the San Francisco area within the next 30 years. This conclusion, together with the 1989 Loma Prieta Earthquake, has increased concerns for the seismic stability of levees protecting islands in the Sacramento-San Joaquin Delta.

Concern exists because the islands in the Delta are generally 10 to 15 feet below sea level. The levees are usually composed of uncompacted sands and silts and are built without engineering design and/or good construction methods. Levees composed of such materials may experience liquefaction and damage during moderate-to-strong earthquakes. The inundation of one or more islands in the Delta during a period of low outflow could result in saline water from the San Francisco Bay being drawn into the Delta. This could significantly impact the export of water as well as numerous other public facilities and resources that afford a wide range of benefits to the people of California.

Generally, foundation soils in the Delta consist of varying amounts of organic soils. Knowledge of the dynamic behavior of organic soils in the Delta is essential for the determination of ground response to earthquake shaking
(Appendix D).

Environmental Issues

5. Habitat Mitigation:
The Long Term Levee Protection Program includes measures to control subsidence, and reconstruct, relocate and maintain levees in the Delta. These measures will likely require significant amounts of fill material to be extracted from sources within and around the Delta, including dredging from Delta channels, and their placement on and around levees. This work may result in significant effects on terrestrial and

aquatic resources. Monitoring and research will help quantify these effects and any necessary compensation (Appendix E).

III. MONITORING AND RESEARCH ELEMENTS

Following is a list of monitoring elements that the CMARP Levees Technical Team recommends be included in the overall assessment of levee integrity and durability pursuant to the Delta Levee System Integrity Program. Each of these monitoring elements, including their respective research components, is described in detail in Appendices A through F. Indicators for each of the Levee Program elements are described in the appendices and in section II of this report.

1. Levee Standard Monitoring Plan: Appendix A
2. Subsidence Control Monitoring Plan: Appendix B
3. Emergency Management and Response Monitoring Plan: Appendix C
4. Seismic Risk Assessment Monitoring Plan: Appendix D
5. Habitat Mitigation Monitoring Plan: Appendix E
6. Common Survey Standard: Appendix F

IV. INDICATORS

Indicators for the goals of individual Levee Program elements are described in detail in Appendices A through F and are summarized below:

Goal: The Base Level Protection goal is to improve and maintain Delta levees to the PL84-99 standard.
Indicator: The number of islands / tracks meeting the minimum PL84-99 standard.

Goal: The Special Improvement Project goal is to provide additional flood protection for key islands that provide state wide and national benefit.
Indicator: The number or levee miles or islands / tracks with enhanced, above PL84-99, flood protection, (Static factor of safety greater than 1.5). It is also suggested that a panel be convened to make a qualitative assessment of progress towards the Special Improvement Project goal.

Goal: The Subsidence Control goal is to reduce or eliminate the risk to the levee system from subsidence.
Indicator: The number or levee miles or islands / tracks with subsidence control measures.

Goal: The Emergency Management goal is to enhance existing emergency and response capabilities.
Indicator: Because of the large number of variables and the qualitative nature of assessing emergency management and response capability, a specific indicator has not been identified. It is suggested that a panel be convened to make a qualitative assessment of progress towards the Emergency Management goal.

Goal: The Delta Levee Seismic Risk Assessment goal is to identify the risk to levees from seismic events and develop recommendations to reduce seismic vulnerability.
Indicator: The number of levee miles or islands / tracks that have received seismic upgrades. (Seismic stability factors of safety greater than 1.0). It is also suggested that a panel be convened to make a qualitative assessment of progress towards the Delta Levee Seismic Risk Assessment goal.

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V. LINKS

There are many areas of overlap between monitoring and research proposed by the CMARP Levee Work Team and other existing programs, CMARP work teams or components of the CALFED Program.

Much of CALFED Program work will require horizontal and vertical control. A single base map/control is critical. Horizontal and vertical datum will be needed by the CALFED storage and conveyance and ecosystem restoration program elements in addition to the Levee Program.

Many proposed components in the "Levee Standard Monitoring Plan," Appendix A, are already being monitored by the DWR Central District as part of its administration of the Delta Levee Maintenance Subventions and Special Flood Control Projects Programs. The Subventions Program Maintenance Criteria presently conforms to the 1986 Flood Hazard Mitigation Plan for the Delta. Many nonproject "local" levees in the Delta have adopted the State's Short Term Levee Rehabilitation Plan standard found in the Flood Hazard Mitigation Plan for the Delta (1986). To continue eligibility for FEMA disaster-assistance funding, these districts have submitted profiles and cross sections documenting minimum geometry and levee profiles to FEMA, the State Office of Emergency Services and the Delta Levee Maintenance Program. Requirements for compliance with the HMP are summarized below:

1) Levee Profile Program participants are required to make a profile of the levee crown not less than every fifth year, of more often if determined necessary by District Board necessary (such as after severe storms).
2) Levee Cross Section DWR retains copies of existing cross sections documenting that levees meet minimum HMP cross section criteria. When districts have brought their levees into compliance with HMP they are required to update cross sections, at intervals no greater than 500 feet, in rehabilitation projects areas. Copies of this information have also been submitted to FEMA.
3) Annual Levee Maintenance Inspection DWR and DFG annually inspect nonproject levees in the Delta in accordance with Water Code Section 12989, the 1986 Flood Hazard Mitigation Plan, and AB360 habitat requirements. The reviews include the following levee maintenance:
   - Vegetation removal, Road surface maintenance, Roadway crown grading, and Gate repair on the levee crown
   - Vegetation removal, Hazard tree removal, Mature tree trimming, Slipouts, Erosion, Cracking, and Subsidence on the land side levee slopes
   - Vegetation removal, Revetment slippage, Slipouts, Erosion, Cracking, and Subsidence of the water side levee slopes
   - Control of encroachments that affect levee integrity
   - Control of rodents that affect levee integrity

In addition, approximately every two years, the U.S. Army Corps of Engineers inspects for those levees with PL 84-99 certification for continuing eligibility.

The bathymetric data proposed in the "Levee Standard Monitoring Plan," Appendix A, to monitor for sedimentation and scour will also be needed by the Storage and Conveyance Program of CALFED. As well, the Ecosystem Restoration Program will require information on sedimentation and scour as it impacts benthic habitat and other ecosystem elements.

Research on sediment toxicity and characterization data proposed in the "Levee Standard Monitoring Plan," Appendix A, is also of concern to the Ecosystem Restoration Plan. The ERP goals include the creation of shallow water habitat, which may involve dredged material. This research is also of concern to the Water Quality Program to quantify water-quality effects from dredge activities and placement of dredged materials.

Some data collection proposed in the "Subsidence Control Monitoring Plan," Appendix B, is currently done by other agencies. The Natural Resources Conservation Service obtains soil property data for publication and some of this information may be applicable to the Plan. The "Subsidence Control Monitoring Plan" also calls for sea-level data, which are collected by NOAA, EPA, and USGS.

Some monitoring proposed in the "Seismic Risk Assessment Monitoring Plan," Appendix D, is currently being done as part of the DWR DOE seismic studies program. This includes installation and monitoring of surface and subsurface strong motion instruments at four locations in the Delta, field and laboratory testing of soils at locations where surface and subsurface seismographs were installed, sponsored research on the dynamic response characteristics of organic soils, and additional dynamic response analysis.

Many monitoring elements proposed in the "Habitat and Mitigation Monitoring Plan," Appendix E, are currently done by DWR's Central District in conjunction with DFG in administering the Subventions and Special Programs Projects. Documentation for participation in the AB360 Program includes habitat assessments in areas where levee work may occur. DWR's Central District has begun compiling this data on a GIS database. In addition, many individual permits for levee construction and maintenance will likely require monitoring for success of mitigation. As well, permits for dredging will likely require monitoring to assess dredge activity effects.

Chapter V, part E. SUBSIDENCE OF DELTA ISLANDS

(this space reserved for a chapter on Subsidence)

Chapter V, part F. STORAGE AND CONVEYANCE

I. CALFED GOALS AND OBJECTIVES

The overall objectives of the CALFED program are to improve ecosystem quality, water supply reliability, and water quality, and to reduce system vulnerability. Unlike the other programs discussed here, storage and conveyance is not a common program of CALFED. Whereas the common programs are included in all CALFED solution alternatives, storage may or may not be included in alternatives. The following types of new storage are being evaluated by CALFED: upstream surface storage, in-Delta surface storage, south of Delta off-aqueduct storage, and groundwater storage. Storage of water in surface reservoirs or groundwater basins can provide opportunities to improve the timing and availability of water for all uses. The benefits and impacts of storage will vary depending on the location, size, and operational policies of the project.

Conveyance describes the various ways that water can be moved through the system to the export facilities in the southern Delta. There are many possible configurations for conveyance.

II. MONITORING ELEMENTS, RESEARCH QUESTIONS, and LINKAGES

This section will discuss projects that address storage and conveyance issues and their resulting monitoring elements and research questions. Linkages between these projects and CALFED common programs are also identified.

Delta channels bathymetry
New topographic and bathymetric maps of the Delta are needed because land surface is subsiding, levee construction and maintenance continues to alter profiles and elevations of levees, and channels continue to adjust hydraulically to altered hydrology and sediment inputs. These maps are needed to implement the Delta Levees Program, plan through-Delta channel modifications and Delta wetland restorations, and to improve Delta water quality simulation models. A hydrodynamic model being developed of the proposed SWP/CVP intake structure and fish-screening facility at Clifton Court Forebay will also need data on channel cross-sections. A U.S. Army Corps of Engineers (USACE) comprehensive study of flood protection on the mainstem Sacramento and San Joaquin Rivers and in the Delta will need land surveys and channel geometry measurements to update a Delta hydrodynamic model.

This work will be useful input to the following CALFED common programs: Ecosystem Protection, Delta Levees, Water Transfers and Water Use Efficiency, and Water Quality.

Streamflow measurement network
The network of continuous streamflow gages in the Bay-Delta watershed has declined over the past decade due to shrinking budgets. An adequate network of gages is necessary to evaluate water availability, water quality, water transfers, water use efficiency, and other aspects of the CALFED program. An inventory of existing gages is

being assembled for CMARP to help evaluate where gaps may exist in the network. The USACE comprehensive flood protection study will also require historic streamflow and stage data at various key locations in the south and central Delta regions, as well as flood hydrographs and flood frequency analyses. The hydrodynamic model being developed of the proposed SWP/CVP intake structure and fish screening facility at Clifton Court Forebay will need data on velocities and surface water elevations.

This streamflow-measurement network will be useful input to all of the CALFED common programs, especially the Water Transfers and Water Use Efficiency program.

Climatic effects on Central Valley hydrology

The range of streamflows that result from climate-driven natural-runoff in the Sierra Nevada has a lot to do with what management plans can and cannot guarantee for ecological health and water quality in the Bay-Delta system. Extreme high and low streamflows can cause effects in the system, which cannot be managed. The frequency and severity of these events need to be determined and incorporated into CALFED planning. Recent modeling efforts have demonstrated that streamflow variations—and potentially, water-management variations—can be forecast with useful levels of skill at lead times ranging from days to seasons. These improvements in snowmelt and rainfall-runoff models have been made possible through improvements in weather and climate predictions.

This work will be also be useful input to all of the CALFED common programs.

Wetlands water use

One approach to improving ecosystem quality in the Delta being considered by CALFED is the conversion of agricultural lands to wetlands. However, an initial evaluation by CALFED staff found that wetlands would increase net water use on the converted lands. This needs to be studied further. Informational needs include (1) evapotranspiration rates of specific vegetative species, (2) operational procedures for proposed wetlands, and (3) development of standardized, pond-specific vegetative compositions. Seasonal wetlands will not use as much water as permanent wetlands. Pond maintenance practices such as dewatering and discing activities will impact infiltration and evaporation losses. The vegetative mix in the wetlands will affect the applied water requirements, vegetative consumptive use, and irrigation efficiencies.

This work will be useful input to the Ecosystem Restoration and Water Transfers and Water Use Efficiency common programs.

Chapter V, part F. WATER TRANSFERS

I. Pertinent CALFED Goals and Objectives

The purpose of the Water Transfers Program is 'to provide a framework of actions, policies, and processes to facilitate, encourage and streamline a properly regulated and protective water market which will allow water to move between users, including environmental users, on a voluntary and compensated basis.' (The CALFED Bay-Delta Program Water Transfer Program Appendix, Early Review Draft, October 1, 1998, 38 p)

A water transfer is the artificial conveyance of water diverted under a legal water right, a contract, or groundwater extraction, from one area to another across a political or hydrologic boundary. Water transfers are being considered as a tool to take an identified supply of "extra" water, and convey that "extra" water to an area where there is presently a shortage of water for beneficial uses. This section of the report will address potential water transfers that involve the Central Valley aquifer system, including transfers that conjunctively involve surface and ground water.

The CALFED Program will not participate in water transfers as a water supplier or user but rather will act to facilitate transfers between willing parties when a proposed transfer meets the goals of the CALFED Program.

CALFED solution principles suggest that water transfers should not:

- raise or lower groundwater levels unacceptably
- induce unacceptable amounts of land subsidence
- unacceptably alter the quality of surface or ground water
- unacceptably increase or decrease groundwater discharge to the land surface, streams, and wetlands
- precipitate unacceptable direct or indirect burdens on the socioeconomics of transfer areas
- provide water for transfer that results in an unacceptable reduction in water claimed by other beneficial users.

II. Monitoring, Assessment and Research Objectives

Monitoring, assessment, and research programs should provide data and information to determine the effect of a water transfer operation on the quantity and quality of surface water and groundwater, land subsidence, the biological system, and the socioeconomic setting, and should pursue the following objectives:

1. Establish background or ambient conditions.
2. Identify and evaluate trends.
3. Define existing or emerging problems.
4. Provide program management guidance.
5. Increase knowledge of natural and human factors affecting the groundwater resource.
6. Comply with statutory and regulatory mandates.
7. Evaluate program effectiveness.

The goal of the proposed monitoring program is to collect the data that will be required to assess the effects of a water transfer.

The goals of the data-assessment program are to define the techniques and procedures necessary to quantitatively evaluate the monitoring data so that 1) effects of the water transfer can be distinguished from other water resource management activities and natural system variability, and 2) assurance is provided that the transfer is operating within established guidelines.

The goal of the focused research program is to improve our understanding of important hydrologic, chemical, and socioeconomic processes to a level that assures that monitoring and assessment are adequate to determine the effects of a water transfer.

CONCEPTUAL MODEL

Central Valley Aquifer System

The Central Valley of California is a north-northwest-trending topographic basin filled with tens of thousands of feet of gravel, sand, silt, and clay derived from the adjacent mountains. Surface water drains from the valley through a single outlet, the Carquinez strait, after passing through the inland delta of the Sacramento and San Joaquin Rivers. The foothill boundary of the Central Valley represents the areal extent of the valley's basin-fill aquifer system. The Central Valley aquifer system has been divided into two subregions— Sacramento Valley and San Joaquin Valley. They are separated by the Sacramento-San Joaquin delta.

Precipitation is more abundant along the east side of the valley, compared with the west side. This precipitation produces runoff that is used for agricultural, groundwater recharge, and urban purposes. For this reason, every major east- side river has a dam and a reservoir. West-side streamflow is intermittent and flashy. Flows from both sides of the valley contribute recharge to the aquifer

The Sacramento Valley Aquifer system has been conceptualized as a single heterogeneous aquifer where aquifer hydraulic properties vary with the proportion of fine-grained sediment. Ground water in Sacramento Valley is generally of good quality. Ground water on the east side of the valley is low in dissolved solids and high in silica, reflecting the quality of recharge water from the mostly granitic rocks of the Sierra Nevada and the metamorphic rocks in the foothills. Reducing conditions produce high concentrations of dissolved trace elements (iron, manganese, and arsenic) near the center of the valley. Ground water on the west side of the valley is lower in silica and higher in dissolved solids concentrations than ground water on the east side. Dissolved solids concentrations generally increase from north to south along the axis of Sacramento Valley.

The Corcoran Clay Member of the Tulare Formation underlies about 5,000 square miles of the San Joaquin Valley, separating the basin fill sediments into a lower confined

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aquifer and upper unconfined to semiconfined aquifer. Groundwater on the west side of the valley contains a higher concentration of dissolved solids than groundwater on the east side. Groundwater on the east side of the valley is characterized predominantly by dissolved calcium, calcium-sodium, or calcium-magnesium bicarbonate. West side groundwater contains mostly dissolved sodium, magnesium, and calcium cations and sulfate and chloride anions.

Land subsidence caused by hydrocompaction of debris flow deposits, and compaction caused by extraction of ground water and hydrocarbons has occurred over wide areas of San Joaquin Valley. Land subsidence from groundwater extraction has also occurred in the southwestern Sacramento Valley.

Groundwater flow and Aquifer Hydraulic Properties

The direction and rate of movement of ground water and solutes in alluvial aquifer systems is controlled by the aquifer geometry, the hydraulic properties of the sediments, and differences in hydraulic head in the saturated zone. Similarly, the relation between flow in streams and an adjacent aquifer is controlled by the interconnection of high permeability sediments between the streambed and the aquifer.

Current knowledge of ground water in California rarely allows accurate prediction of where or when stream flow depletions will occur as a result of groundwater extraction. Surface flow decreases caused by ground water pumping increases could take place in a few days, a few weeks, or many months.

Baseline hydrogeologic characterization data are needed to adequately assess the movement of water and solutes in response to a water transfer. In addition, the ability to define areas of potential land subsidence and aquifer compaction is dependent on an accurate assessment of the spatial distribution of clay layers throughout the aquifer. Although there have been several studies on the geologic structure of the Central Valley, there are many gaps in the understanding of the overall structure of the aquifer, and very few detailed characterization studies have been completed.

Water balance

The availability of water resources in a particular area might be considered by a simple water balance:

$$\textit{Inflow} - \textit{Outflow} = \textit{Change In Storage}$$

Each term in the simple balance equation has many components that must be measured or estimated. Surface water resources are quantified and managed by measuring runoff, reservoir level, releases, and water use. These components of the surface water balance provide a means of closely managing the resource. In contrast, 3 equivalent components are absent in the management of groundwater resources--recharge to the aquifer, extraction (pumpage), and water use. Without these components of the groundwater balance, it is difficult, if not impossible, to manage groundwater resources to the same degree as surface water.

Implementing a water transfer will alter the water balance (both groundwater and surface water) for the area transferring the water and for the area receiving the water. Because ground water and surface water are dynamically linked, determination of the water balance must integrate components of both ground water and surface water. Groundwater levels, stream stage and discharge, and water levels in wetlands or other surface water bodies are all affected by changes in the overall water balance for the basin.

Under natural conditions, the amount of recharge (inflow) is equal to the amount of discharge (outflow), and changes in storage are minimal. However, stresses on the groundwater system, such as pumping, changes in stream discharge, and variations in net infiltration due to irrigation, alter the natural balance and result in a change of storage. Storage changes are reflected by fluctuations of water levels in the aquifer. Conjunctive use and artificial storage and recovery projects require water quality information to assess impacts and evaluate the success of any program.

Water balance calculations will help to define whether water proposed for sale is new, real, or paper water (see Water Transfers appendix for definitions).

<u>Socioeconomic Factors</u>
There may be unintended effects on those not a party to a water transfer, such as adverse effects on other legal water users, local economies, and environmental resources. Indicators that could identify potential changes should be monitored.
It is generally recognized that certain types of transfers can have adverse impacts on local economic conditions. Fallowing transfers, for example, may result in lower agricultural production in the source area and may impact local employment of farm workers and others. Groundwater transfers or transfers of surface water with groundwater replacement may result in lower groundwater levels, lower groundwater quality and higher pumping costs for other local groundwater users. In extreme cases, impacted groundwater users may lose the use of existing wells because of water quality degradation, lower groundwater levels.

III. MONITORING PLAN ELEMENTS

To achieve monitoring and research objectives, two scales of monitoring are required: regional and site specific. The data collected from regional and site-specific networks complement each other, and provide a comprehensive evaluation of the effects of a project. Regional data are adequate for detecting generalized trends or gross changes in flow patterns, water quality, or land surface elevation.

Site-specific monitoring measures the effects of a particular project on local conditions, such as local pumping depressions, water quality, sensitive environmental habitats or local economies. Site-specific monitoring should be of sufficient detail to provide a means of distinguishing between the effects of the project and of other ongoing activities in a particular area. Design of site-specific monitoring networks at groundwater extraction sites will depend on details provided during site characterization studies.

In both types of monitoring networks, establishing baseline conditions is essential to assess the effects of the project. Assessment of the effects of water transfers, especially during the initial phases of a transfer, will of necessity rely heavily on the regional baseline data.

Without improvements to existing monitoring networks, the ability to adequately assess the effects of water transfers is severely limited (see Water Transfers Appendix).

MONITORING AND ASSESSMENT

Hydrogeologic characterization

Characterization of aquifer structure and boundaries includes the following components:

1. aquifer geometry
2. degree of confinement
3. regional scale mapping of hydrogeologic boundaries, including:
   - major stratigraphic boundaries reflecting changes in depositional environment
   - single depositional units that restrict vertical flow over broad areas
   - bedrock structure
   - faults
4. local scale mapping of hydrogeologic units, to define the spatial variability of aquifer hydraulic and mechanical properties
5. delineation of aquifer boundaries using water chemistry characteristics (isotopes, major ion composition)

Water balance

The following components must be determined to estimate changes in the water balance as a result of a water transfer: These data need to be monitored at a regional scale to provide context for local scale studies.

1. Groundwater levels
2. Stream stage and discharge
3. Surface water deliveries
4. Net infiltration (precipitation + applied water – return flow – ET)

Land Subsidence

1. Paired aquifer compaction and discrete-interval, groundwater-level recording installations at groundwater extraction sites.
2. Land surveys coordinated with regional Geodetic networks.

Water quality

1. Ground water quality and temperature
2. Surface water quality and temperature

Socioeconomic Factors

1. Agricultural employment
2. Rural business sales and employment
3. Population
4. Cropping pattern and acreage
5. Number and size of farms
6. Value of agricultural output
7. County tax collection and expenditures
8. Labor force and unemployment

IV. RESEARCH

The research questions relevant to water transfers are an extension of questions that are relevant in the design of a groundwater monitoring and assessment program. Research into the following subjects would greatly improve the ability to manage groundwater in the unsaturated and in the saturated zone.

- Vadose zone processes and rates of recharge
- Interaction of regional- and local-scale processes
- Better methods to quantify interaction between ground and surface water
- Effects of climate variability on watershed processes
- Improved methods storage, manipulation, and coordination analysis of data
- Land subsidence processes and predictive capabilities
- Scale variant hydrogeologic characterization
- Processes controlling water quality including the effects of increased rate and volume of extracted groundwater on water quality
- Effects of water transfers on persons, businesses or agencies that are not a party involved in the transfer (3d party effects)

V. LINKAGES

Water Quality Program: The Water Transfers Monitoring Program refers to the Water Quality Program for quantitative information on stream flow and stream chemistry at all monitored sites in the Central Valley.

Storage and Conveyance Program (as well as the California Department of Water Resources, Division of Operations and Maintenance and Office of State Water Project Planning, and the U. S. Bureau of Reclamation, Central Valley Operations Office): The Water Transfers Program refers to these agencies for information regarding the availability, and suitability of conditions for water transfer through surface water conveyance facilities.

Ecosystem Restoration: The ecosystem restoration program must assess the ecological suitability of water transfer through the riverine and deltaic environments.

Water Use Efficiency Program: The Water Transfer Monitoring Program relies on information compiled under the Agricultural and Urban Water Conservation components of the Water Use Efficiency Program to assess future water supply and demand in the state to determine transfer needs, and to provide detailed land and water use information for water balance determinations and socioeconomic considerations.

Watershed Management Program: The effects of water transfers on riparian corridors, wetlands, and stream basins upstream of the Central Valley need to be monitored and assessed by the Watershed Management Monitoring Program. The Water Transfers Program also relies on the Watershed Management Program for information on spatial and temporal input of precipitation to the Central Valley.

Various local, state, and federal agencies (See Water Transfers Appendix): Socioeconomic information adequate to assess the economic effects of water transfers will have to be provided by agencies exterior to the CALFED program.

Chapter V, part H. WATER USE EFFICIENCY

1. CONSERVATION

The CALFED Program addresses four categories of Bay-Delta problems: ecosystem quality, water quality, water-supply reliability and system integrity. Water-use efficiency is clearly related to the goal of improving water-supply reliability, and can help achieve other program objectives by improving water quality or enhancing ecosystem health. CALFED has based their Water Use Efficiency Common Program (WUECP) for conservation on improved urban and agricultural water management planning, technical and financial assistance, and the resultant implementation of cost-effective urban Best Management Practices and agricultural Efficient Water Management Practices.

<u>Agricultural Water Use and Conservation</u>

The monitoring objectives for agriculture must address questions that show WUECP is succeeding well enough to assure various stakeholders of its effectiveness. To determine the WUECP's effectiveness, the following questions need to be answered for the agricultural sector in the CALFED solution area.

1. How many endorsed agricultural water-management plans exist in the CALFED solution area, how many are completed but not endorsed, and how many acres do they represent?
2. Which EWMPs are being implemented and what is the magnitude of their implementation?
3. Have the EWMP's achieved permanent reductions in growing-season-applied water or depletions for crops, and are sufficient mechanisms in place to maintain their effectiveness?
4. What is the relationship of the water applied to crops and their actual needs (evapotranspiration of applied water/potential irrigation efficiency) at the farm, district and regional levels?
5. Are increased planning and assistance programs reducing applied water and depletions beyond the projections in State and local plans?
6. Has the reduction in applied water had positive, negative or neutral effects on third-parties and the environment?

In general, the measurement needs for determining agricultural water use efficiency within the CALFED Solution Area include:

1. Land-use surveys every five years of all agricultural counties with more than 50,000 irrigated acres, to be consistent with updates of the California Water Plan. The land-use surveys must include water source and irrigation method, by crop.
2. Annual land, soil, and water-use survey of the Delta including real-time ET data for the Delta lowlands.
3. Data of water applied on agricultural fields are needed for all irrigation, for a number of irrigation seasons, and for surface- and ground-water sources. Estimation of the distribution uniformity of individual irrigation, and seasonal application efficiency are necessary to estimate the optimization of on-farm water use, on an annual basis.

4. Estimates of the reuse of surface and subsurface drainage water and ground water to quantify the relationship of on-farm efficiencies to higher district and regional efficiencies. Initial data gathering should be done over a three-year period and updated every five years thereafter.
5. Annual update of acreage using various irrigation methods including estimates of their efficiency based on a standardized set of assumptions and formulas.
6. Annual review and update of crop coefficients for estimating crop water use to be used in annual water balances by planning sub-areas.
7. Length of all canals and laterals (lined and unlined) linked with areas being irrigated by various irrigation methods, using GIS and GPS technology to be used in the determination of evaporation and seepage.
8. Documentation of EWMPs to be implemented from agricultural water-management plans, with particular attention to those practices related to improving water delivery, measurement, and pricing.
9. Documentation of environmental and third party effects of conservation measures from the implementation of EWMPs.
10. Annual documentation of crop rotation and fallowing sequences because of agronomic practices or government programs.

Major gaps in knowledge of irrigation efficiency and crop water use should be filled to help CALFED and CALFED agencies reach their objectives. The priorities for such research would be:

1. Development of a complete and improved set of crop coefficients (Kc) for all 250 California crops;
2. Determination of the feasibility of attaining distribution uniformities (DU) greater than 80 percent for re-designed and manufactured irrigation equipment;
3. Evaluation of improved agronomic practices that would increase yields while reducing resource inputs and improve sustainability; and
4. Development of new crop varieties that would have the same effects as #3 above.

Urban Water Use and Conservation

The objectives for the monitoring program in the urban sector need to assure stakeholders of the effectiveness of the WUECP. Similar questions to those posed for agriculture, above, need to be asked for the urban sector in the CALFED solution area.

1. How many certified urban water management plans exist in the CALFED solution area and how many remain uncertified?
2. Are BMPs being effectively implemented, and are they being implemented within the criteria established by the California Urban Water Conservation Council?
3. Have the BMPs achieved permanent reductions in applied water or depletions, and are sufficient mechanisms in place to maintain their effectiveness?
4. What is the relationship to the theoretical need (or efficiency on a per-capita water use basis)?

5. water and depletions beyond the projections in state and local plans?
6. Has the reduction in applied water had positive, negative or neutral effects on third parties and the environment?

Chapter V, part H. Water Use Efficiency

2. Water Recycling

Monitoring Objectives and Research Needs

The CMARP monitoring objectives for water recycling are based on the goals of CALFED's Water Use Efficiency common program, which estimates a potential for recycling between 1.4 to 2 million acre-feet a year by 2020. (For more details and a description of laws and regulations governing water recycling in California, see the Water Use Efficiency Technical Appendix to the Programmatic EIS/EIR.) The policy framework for implementing CALFED's preferred program alternative states that Stage 1 of implementation will be a 7-year period that starts when the Programmatic EIS/EIR is certified. During this period, information about the effects of CALFED's WUE common program will be gathered and analyzed as the program is implemented. Findings from the analyses will be used to determine the performance of CALFED WUE program actions and change program management to improve performance if necessary.

The role of CALFED agencies in carrying out the Water Use Efficiency Program is to encourage and build upon local and regional implementation of efficiency measures. CALFED agencies are to: (1) offer support and incentives through expanded planning, technical, and financial assistance; and (2) provide assurances that cost-effective efficiency measures are implemented. With regard to water recycling, the Water Use Efficiency Program includes the following actions to encourage water recycling statewide:

- Help local and regional agencies comply with the water recycling provisions in the Urban Water Management Planning Act.
- Expand state and federal recycling programs in order to provide sharply increased levels of planning, technical, and financing assistance, and develop new ways of providing assistance in the most effective manner.
- Provide regional planning assistance that can increase opportunities for use of recycled water.

These actions are expected to reduce demand for Delta exports, increase availability of water for transfer to other users or for environmental flows, and improve water quality in the Delta and its tributaries. In addition, they should help California reach the water recycling goals adopted in Water Code Section 13142.5(e): 700,000 acre-feet/year by 2000 and 1 million af/yr by 2010. To assess the extent to which the above actions reduce demand and improve water quality, more accurate data are needed about the following:

- quality of the source water available for recycling
- amounts of water available for recycling (amounts of wastewater being generated)
- amounts and quality of recycled water produced by treatment plants
- costs of producing and delivering the recycled water
- amounts of recycled water actually used and distribution of those uses
- benefits derived from uses of recycled water

In addition, financial and cost data for existing water recycling projects would allow CALFED to forecast financial assistance that may be needed to achieve the estimated water recycling potential.

Goals and Objectives of the Monitoring and Research Plan for Water Recycling

Monitoring Goals. To assess local agencies' responses to CALFED water recycling program actions, monitoring and data gathering during years 1 through 5 of Stage 1 implementation will focus on the following key indicators:

- quantities of wastewater collected and treated
- amounts and quality of recycled water produced by treatment plants
- quantities of recycled water delivered to various uses (agriculture, municipal and industrial, landscape irrigation, habitat restoration or enhancement, or stream flow augmentation)
- the effects of water quality on the amounts of recycled water produced and on the end uses of the recycled water
- the capital outlay and other costs of producing and distributing the recycled water
- the prices charged for delivery of recycled water to water retailers

Analyses of data about the above indicators will allow CALFED agencies to determine the cost-effectiveness of water recycling projects and the quantities and quality of water actually delivered and used. These determinations will allow CALFED to: (1) better determine the effects of water recycling on water supply reliability and water quality; (2) assess where and when its planning, technical, and financial assistance are most effective; and (3) refine and target future CALFED water recycling assistance.

Research Objectives. Several interests have argued that the ranges of future recycled water production in CALFED's PEIS/PEIR will not be attained unless certain actions are taken and additional incentives are provided to local agencies. Comments about the draft PEIS/PEIR described an array of hurdles to project development and implementation, and comment letters suggested the following actions for resolving some of the implementation issues:

- More closely coordinate actions taken by the Department of Health Services, the State Water Resources Control Board, the Regional Water Quality Control Boards, and the California Plumbing Standards Commission. Resolve any differences that may exist between requirements set forth in the Uniform Plumbing Code and DHS policy regarding recycled water and potable water pipelines.
- Provide incentives for local water and wastewater agencies to coordinate their water recycling efforts.
- Remove the institutional hurdles to efficient sale and transfer of recycled water among water and wastewater agencies.
- Provide clear, concise guidance on and assistance with accounting for all benefits of proposed recycled water projects in cost-benefit analyses and other planning studies required by state and federal regulatory agencies.
- Conduct a statewide economic evaluation of water recycling that quantifies the pollution prevention, hydrologic, economic, and environmental effects of reductions in water diversions stemming from increased water recycling.

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- Assess the potential for water recycling to help achieve water supply augmentation, reliability, and water quality and ecosystem health objectives of CALFED and evaluate these potential benefits.
- Provide ongoing public outreach and communication about the high value of recycled water, and improve public understanding of the water quality goals in Title 22 of the California Code of Regulations.

To address these suggestions and help assure effective implementation of the CALFED Water Use Efficiency Common Program, CMARP research could investigate the following:
- Interactions among and program policies or regulations of DHS, SWRCB, the Regional Water Quality Control Boards, and the California Plumbing Standards Commission
- The economics of water recycling
- Existing statewide infrastructure available for the treatment, transport, and storage of recycled water
- Effects of source water quality on the costs of producing recycled water
- Public perception and acceptance of recycled water for various uses

See the technical appendix for further research needed to encourage the beneficial use of recycled water.

Linkages to Other CMARP Elements
A major factor in the production, distribution, and use of recycled water is water quality. The quality of water entering treatment plants directly affects the levels and amount of treatment necessary. The quality of the recycled water produced affects the types and amount of beneficial reuse. Therefore, a link between CMARP's water use efficiency and water quality elements is necessary. Water quality monitoring and research data useful for refining CALFED's water recycling program management include:
- A comprehensive assessment of salinity sources in wastewater collection systems
- Impacts of salt accumulation on agricultural products and sensitive turf areas
- Fate and transport of salts, organics, disinfection byproducts, viruses, protozoa,
- and bacteria in ground and surface waters
- Effectiveness of using constructed wetlands to remove nitrogen
- Toxicity and disposal of brines resulting from use of membrane technologies
- Impacts of recycled water on valves, seals, and O-rings
- Information about the levels and amount of treatment required to lower the risk of adverse health effects stemming from disinfection byproducts, viruses, protozoa, and bacteria in water and wastewater
- Adequacy and refinement of microbiological risk assessment methodologies
- Real-time pathogen monitoring techniques
- Adequacy of treatment in the vadose zone (groundwater recharge systems)
- Evaluation of sources of recycled water other than urban wastewater (for example, process rinse water)

Chapter V, part I. WATERSHED MANAGEMENT

I. PERTINENT CALFED GOALS AND OBJECTIVES

Watershed Management Program Goal:
To help coordinate and integrate existing and future local watershed programs and to provide technical assistance... for watershed activities relevant to achieving the goals and objectives of the CALFED Bay-Delta Program.

Watershed Program objectives addressed in the monitoring plan:

- Describe the basic biophysical functions and processes of a watershed, including linkages from upper watersheds--to lower watersheds--to the Bay-Delta.
- Identify watershed functions and processes relevant to the CALFED goals and objectives
- Describe how land use and other human activities affect and are affected by watershed functions and processes
- Illustrate benefits that accrue from watershed plans and projects designed to favorably affect the CALFED goals and objectives
- Provide monitoring assistance to aid watershed organizations.

Ecosystem restoration objectives addressed here:
Rehabilitate the capacity of the Bay-Delta estuary and its watershed to support natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities, with minimal ongoing human intervention.

Water quality objectives:
Improve water quality for environmental, agricultural, drinking water, industrial, and recreational beneficial uses of water.

Geographic scope: watersheds at all scales within the CALFED solution area. The Watershed Program supports whole-watershed approaches. Consequently, at larger scales, there is overlap between the geographic purview of the Watershed Program and other CALFED programs that focus on the Bay-Delta and the alluvial Central Valley.

II. GOALS AND OBJECTIVES OF THE WATERSHED MONITORING PLAN

<u>Problem Statement</u>
Physical landscape and history of human actions together shape the watershed processes relevant to CALFED. Watersheds shape downstream system characteristics by affecting flow and sediment regimes, water quality, and flood hazard. Conditions in watersheds affect species of the Bay-Delta, especially those that move out of the lower reaches during part of their lives. Habitats in watersheds support populations and species that are integral to regional ecosystem integrity and biodiversity. Productivity and characteristics of vegetation in watersheds affect nutrient inputs to the Bay-Delta, and together shape carbon exchange with the atmosphere.

Humans live and work in watersheds, changing the landscape in ways that affect flow and sediment regimes, vegetation, water quality, and availability of suitable habitats. Humans, in turn, are affected by availability and quality of water for various uses, economic exchanges related to water and water management, and maintenance of ecosystem and habitat functions that support resource-dependent livelihoods and valued species. Costs of watershed improvement are incurred by communities that may or may not receive the economic benefits of improved water quality or quantity. Likewise, downstream environmental and economic costs are not necessarily accounted for in land-use decisions that affect watershed function.

Monitoring Goals

Efforts to improve watershed function with respect to CALFED goals focus on modifying human actions in ways that will achieve desired results and reverse adverse effects of past actions. To do this effectively, we need information that allows us to analyze both the biophysical and human components of the system:

- evaluate and prioritize actions in terms of potential to affect both downstream and local conditions
- evaluate effectiveness of actions and make appropriate adjustments
- evaluate the economic and social consequences of watershed improvement actions for both local and downstream communities.

Actions undertaken by local communities and agencies are central to program success, so this information must serve local needs as well as needs of CALFED agencies. The goal of the Watershed Monitoring Plan is to provide a framework for serving these information needs.

Watershed program information needs fall into two distinct categories:

1. Provide information on watersheds, as they relate to trends and processes in the Bay-Delta, including assessment of cumulative effects of changes in land-use and management practices on those processes and changes due to CALFED actions.
2. Evaluate effectiveness of particular practices in achieving desired results, detect and evaluate cumulative effects and trends, and provide for information exchange locally and regionally to facilitate adaptive management for local watershed health and development of community-based institutions for watershed stewardship.

These two categories of goals address the same set of ecological and social processes, but focus at different scales, where different process attributes come to the forefront. We highlight these contrasts in our discussion of monitoring elements (see appendix). At all scales, hydrologic processes are strongly influenced by background characteristics of landscape, weather, and past history of natural and human-related change. In addition, extreme events at irregular intervals have large effects on system characteristics. Consequently, the problem of detecting trend and change due to management against this background of large and irregular spatial and temporal variation is a central issue at all scales. We identified central integration of background landscape and climatic information, current and historic, in forms readily usable for watershed-based analyses at all scales as an important component of the monitoring program, one that will facilitate local monitoring efforts while meeting CALFED's internal needs for this information.

The overall monitoring program we propose employs data collection and analysis at three scales:

1. Trend monitoring for basins and sub-basins (CalWater Hydrologic Units and Hydrologic Sub-Areas)
   This is the scale at which information on input to the Bay-Delta system is needed to interpret ecosystem response and water-management implications of trends. Monitoring at this scale focuses on flow regime, water quality, and sediment regime characteristics measured at the lower end of the watersheds, interpreted in light of
   - long-term and current weather,
   - basin geology, landforms, and vegetation, and
   - broad patterns of change in land use and vegetation related to agriculture, urbanization, road construction, and logging. Interpretation of relationships between observed trends and management actions at this scale is mostly indirect, based on projections from observations at smaller scales (see 3. below). Analysis of regional trends spatial extent and configuration of habitats is appropriate at this scale. Existing monitoring systems and landscape data are adequate for many parameters, although substantial effort will be required to integrate data from diverse sources and convert them into forms that can be readily analyzed, by watershed. Trends in population and habitat conditions for species of special concern will also be evaluated. Trends in species distributions (composite analysis of range extensions and contractions for native and exotic species in representative groups) will be evaluated, as systems for tracking these attributes become active at local levels.

2. Trend and cumulative effects monitoring at CalWater Planning Unit scale
   This is the scale at which relationships between watershed health attributes and trends in land-use and management practices can be realistically differentiated from background variation. Local governments, citizen groups, and agencies often make management decisions and conduct planning at this scale. Interpretation of trends observed at larger scales relies on consistent monitoring of a core set of watershed attributes, together with development of a system for summarizing and providing access to data across watersheds and regions. However, at this scale, local concerns and objectives, local institutions, and characteristics of local landscapes appropriately take major roles in shaping monitoring programs. Consequently, it is not appropriate for CALFED to recommend a uniform monitoring program beyond the limited set of core attributes. Instead, we propose developing a set of prototype monitoring programs addressing different objectives in different landscapes to serve as templates and/or points of departure for locally developed monitoring programs.

3. Project Level Effectiveness Monitoring and Research (small watershed or stream reach)
   Although cumulative effects of land-use trends may be detectable at larger scales, effective adaptive management feedback and estimates of program success rely on focused monitoring of contrasting practices at very small scales. A network of small monitoring sites based on a stratified-random sampling design may be appropriate for monitoring trends at larger scales for some elements. We recommend this approach for habitat quality/species distribution monitoring in particular.

III. MONITORING ELEMENTS

Flow and Sediment Regimes
Geology, landforms, climate and weather, and regional vegetation patterns largely shape characteristics of flow and sediment regimes. However, these processes are affected by activities that accelerate erosion and alter runoff/infiltration relationships. Roads and agriculture are of particular concern at all scales, as are increased rate of slope failure associated with logging and wildfire. Activities that directly alter streamflow and ground water have major effects on flow and sediment regimes downstream. Dams, diversions, ground water pumping, irrigation practices, and urban runoff are of concern. Activities that affect stability and roughness of channels, banks and floodplains, directly or via vegetation modification, also affect sediment regimes. Again, roadbuilding and agriculture are major concerns for direct effects, and logging and grazing affect riparian vegetation in some areas. At large scales, broad patterns of land-use change produce significant, detectable effects on sediment and flow regimes. More subtle differences in land-use patterns and management practices have effects that, although indistinguishable from background variation several miles downstream, have major consequences for local habitat values.

Necessary descriptive/baseline information and monitoring elements include: Geology and Landforms; Climate; Weathering; Upland Vegetation; Riparian Vegetation; Land and Water Use; Weather; Water Yield (including groundwater); Streamflow; Sediment Yield; Sediment Transport

Water Quality--includes elements of water temperature, suspended sediments, and undesirable chemical constituents from natural sources and human activities. All activities of concern with sediment production relate to water quality. Agricultural and forestry practices are of additional concern because of pesticide inputs. Effects that reduce channel shading affect water quality by elevating water temperature and affect riparian vegetation. These include wildfire, logging, and grazing. Input of contaminants from urban and industrial sources is an additional part of the water-quality picture.

Monitoring elements are described in the Water Quality Program monitoring plan.

Habitats--Regional biota are largely shaped by the range of habitats present. Human activities have substantial effects on the extent of habitats and maintenance of processes and conditions that support survival and reproduction of species. Alteration of flooding regime and disruption of sediment supply due to dams, levees, and gravel mining have drastically altered channel geomorphic processes, severely affecting habitat values and successional process. Modification of riparian vegetation and alteration of flooding regimes affects primary production and transfer of nutrients from the terrestrial to the aquatic system as well as habitat physical structure. These changes have ramifications for community composition and species diversity across many species groups, locally and downstream. Habitat destruction and fragmentation from agriculture and urbanization, loss of pollinators and dispersal agents through pesticide use and other effects, and introduction of exotic species further limit ability of landscapes to support the full complement of native species that have been present historically. Wetlands like those that once occupied much of the Central Valley have very high rates of primary production and accumulation of organic detritis, serving as sinks of atmospheric carbon. Loss of wetlands, coupled with agricultural practices that cause net loss of organic matter from soils,

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especially peat soils of former wetlands, have altered the regional atmospheric carbon budget. Monitoring should address implications of wetland restoration and agricultural practices on regional carbon budgets in order to address current concerns about effects to global climate change as well as consequences for community trophic structure.

Monitoring elements in addition to those mentioned previously include:
Carbon Dynamics; Habitat Spatial Extent and Configuration; Biotic Communities; Population Dynamics and Distribution of Species; and Habitat Quality

Economic/Demographic--Human population, demographics, and patterns of economic activity largely shape nature and magnitude of effects to watershed conditions. Improvement of watershed function requires modification of land-use and management practices, with associated costs, benefits, and other consequences for local and distant communities.

Monitoring elements--Human Population, Demographics, and Patterns of Economic Activity Economic Costs and Benefits Related to Water Quality and Flow Regime

Watershed Action/Education--Education and community values influence and are influenced by watershed improvement actions, and are consequently important elements in analysis of program effectiveness.

Monitoring element: Community-based Watershed Improvement Activity

IV. RESEARCH QUESTIONS

Applied research on watershed restoration practices is a high priority, along with structured monitoring of restoration project effectiveness. Research at small scales on implications of alternative agricultural, forestry, and road construction practices on flow and sediment dynamics is needed for interpretation of system trends and program effectiveness at larger scales.

Development of baseline data resources and GIS tools for analysis of physical, biotic and cultural characteristics of landscapes is essential for analysis of trends and management effects. Restoration and further development of precipitation, streamgage, and snowpack monitoring networks is needed to provide data at appropriate scales for effectiveness and cumulative effects monitoring. Development and integration of this information into useful, multipurpose, web-accessible databases are a technological challenge and research need.

V. LINKAGES

Ecosystem Restoration: Watershed monitoring provides information on flow, sediment, water quality, and nutrient dynamics relevant to analysis of ecosystem characteristics and habitat quality in the Bay-Delta, as well as feasibility of restoration of channel geomorphic processes. It also provides data on habitat availability and quality for species that use habitats outside the Bay-Delta. Watershed monitoring provides the basis for analyzing trends in land-use practices that have major effects on the Bay-Delta ecosystem.

Water Quality: The Watershed monitoring program refers to the Water Quality program for description of elements related to natural and anthropogenic dissolved constituents and contaminants and design of a program to provide data for assessing effectiveness and cumulative effects of watershed improvement actions. Watershed monitoring provides information on land-use patterns, sediment delivery and transport data, and biotic response related to water quality.

Water Transfers: Watershed and Water Transfers monitoring programs share a need for detailed baseline information on geology, geomorphology, weathering, and climate. Both programs address effects of land-use patterns on groundwater dynamics and use. We refer to the Water Transfers monitoring program for description of elements related to groundwater measurement, agricultural practices, demographics, and patterns of economic activity.

Delta Levees: Watershed conditions have implications for flood risk, and sediment regimes have implications for channel maintenance. Watershed and Delta Levees programs share a need for information on extreme precipitation and flow events, although the scale of focus differs because of the need here for analysis of alternative management actions and land-use trends in small watersheds.

Storage and Conveyance: Watershed monitoring contributes information on flow and sediment regimes relevant to water availability and maintenance of storage capacity in reservoirs. It also provides information on land-use practices relevant to interpreting trends in flow and sediment regimes. Storage and conveyance monitoring provides information relevant to estimating consequences for downstream users, including economic costs and benefits, associated with watershed improvement and land-use trends.

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Chapter V, part J. Category III Projects, Monitoring and Data Review

Early in its planning stages, CMARP recognized the need for review of monitoring activities for the projects being implemented through the Category III Program. The Category III Program was initiated to implement environmental restoration projects to provide immediate benefits as an early implementation step of the CALFED environmental restoration plan. During 1997, more than 70 projects were authorized for funding through Category III. During 1998, more than 60 more were authorized. Feedback on Category III project effectiveness will be important in laying the framework for subsequent decisions on funding other projects and on water project operations.

CMARP, in general, is tasked with defining the longer term monitoring and assessment needs associated with CALFED Stage 1 actions and, additionally, with assessing the effectiveness of Category III projects. Accordingly, CMARP has developed a process to provide review of Category III project monitoring plans, and is developing an infrastructure to provide a review of data/project effectiveness as information from those projects become available.

The process developed and utilized for Category III projects, presented schematically in Figure 1, emphasizes the use of a technical workgroup to provide review of the monitoring activities of the projects. Note that "monitoring" was defined broadly to include any kind of data acquisition that would, hopefully, be supportive to the increase in knowledge and understanding of the system and/or project effectiveness. While not all projects would have a restoration-monitoring plan per se (such as a research project not doing restoration), most projects are appropriate to the broader data-acquisition definition.

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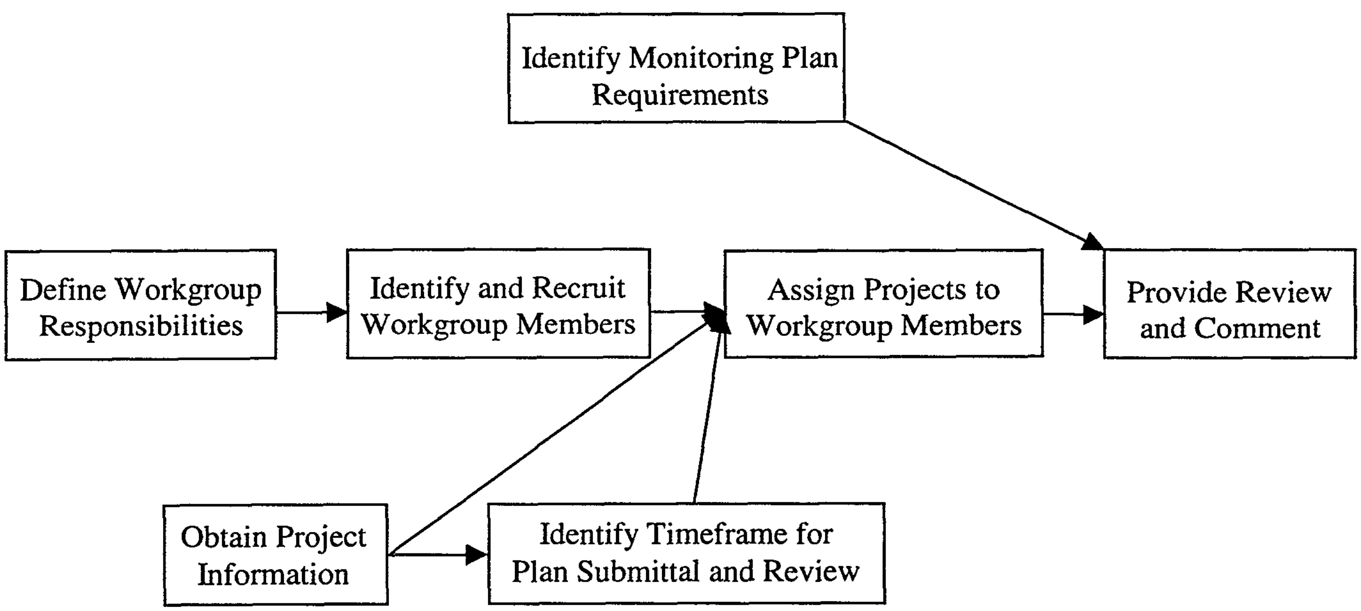


Figure 1 - Category III Monitoring Workgroup Process

Workgroup Responsibilities

The first task was to clarify the scope of responsibilities of the workgroup. Several potential activities that this workgroup could be responsible for and/or involved with, include:

A. Review and comment to project proponents on monitoring, reporting and assessment plans for ongoing and planned Category III projects.
B. Review and assessment of monitoring data/information (at various levels - satisfactorily meeting project objectives; adequacy of data evaluation; evaluation/ assessment/ interpretation of data relative to other data on local basis; and evaluation/ assessment/ interpretation of data relative to overall ecological/biological objectives).
C. Data clearinghouse
D. Development and/or guidance on monitoring protocols/indicators/strategies for future projects.

The initial focus of the workgroup was identified to be item (A) and at least the first level of evaluation in item (B). The workgroup will not provide review of general project management, planning and construction aspects of the project except as it specifically relates to biological/ecological monitoring.

The CMARP steering committee recognizes the need for all of the above activities, and is developing approaches for the long-term program. A need, however, for a near-term implementation approach, necessarily to be consistent with a long-term program, to include these additional elements currently exists. For example, feedback to the CALFED Integration Panel on the effectiveness and related issues in implementing projects is critical to making new/additional funding recommendations as part of the FY99 and FY2000 funding decisions. This may not include yet include evaluation of project data and conclusions, but does include information on how the implementation of projects is progressing, including clarification of project objectives, hypotheses and monitoring methodologies. Also, a process/system for the centralization and sharing of project information and data from the ongoing Category III projects needs to be developed and implemented. The data collection includes project descriptions, data, analysis, mapping, monitoring methodologies, etc. The efforts to describe monitoring methods and protocols used in the ongoing Category III projects will serve as a basis for future projects, and thus suggests the importance of developing a means of collation and distribution of that information. The existing workgroup could serve a role in developing and implementing these necessary near-term elements.

The Monitoring Plan Review Process

A parallel task to developing the workgroup responsibilities was to recruit a qualified workgroup of technical specialists. Because of the variety of technical specialties within the various projects, a diverse group was needed. Approximately twenty agency and non-agency personnel were recruited, based primarily on their technical abilities and availability.

Figure 5.I.2: An outline of information expected to be in the monitoring plan

Project and Monitoring Objectives	--include objectives, hypotheses, assumptions, and conceptual framework/models
Monitoring Approach and Design Methodology, with supportive rationale	--duration, frequency, type of equipment, constituents, locations, integration with other projects, etc. --provide references or copies of protocols being followed
Data Sampling Procedures	--number and type of samples, handling, preservation, storage, analytical techniques, data synthesis and analysis
Analysis and Reporting	--report frequency, content and format; evaluation approach, use of peer review; metadata, data management and format; etc.

Individual project information was collected, including the executive summary from the original proposal, the most recent scope of work, and monitoring plans, if available. For projects without monitoring plans per se, the scope of work served to provide much of the above information and was used for the review. The project packages were also used to help develop an understanding of the timeframe for submittal of monitoring information appropriate to each project.

Projects were assigned to members of the workgroup based on their technical knowledge. At least three members were assigned to each project, although most projects had more members assigned. Project packages were distributed based on the assignments. Review comments are being coordinated and consolidated through the workgroup chair.

Currently, monitoring plans are being reviewed or information is expected from project proponents. Project data/conclusion review is premature, but the intent is to soon begin developing the process by which data/conclusions will be reviewed, shared with interested parties, and integrated into the decision-making process for the next funding round.

Recommendations based on the Ongoing Category III Monitoring Review Process

The experiences of the Category III review process provide useful information for the developing CMARP and related CALFED processes. Some of the more important points are:

1. Early review of monitoring and research methods is needed, ideally as soon as the project is authorized to be funded to assist in finalizing the scope of

work and budgets. A standard format would be useful to emphasize the need to articulate and link the objectives, conceptual models, assumptions, hypotheses and the methods. This shift toward increasing communication of thoughts and concepts appears to be threatening and bothersome to many. A cooperative spirit from everyone involved is critical to effectively developing and implementing projects.

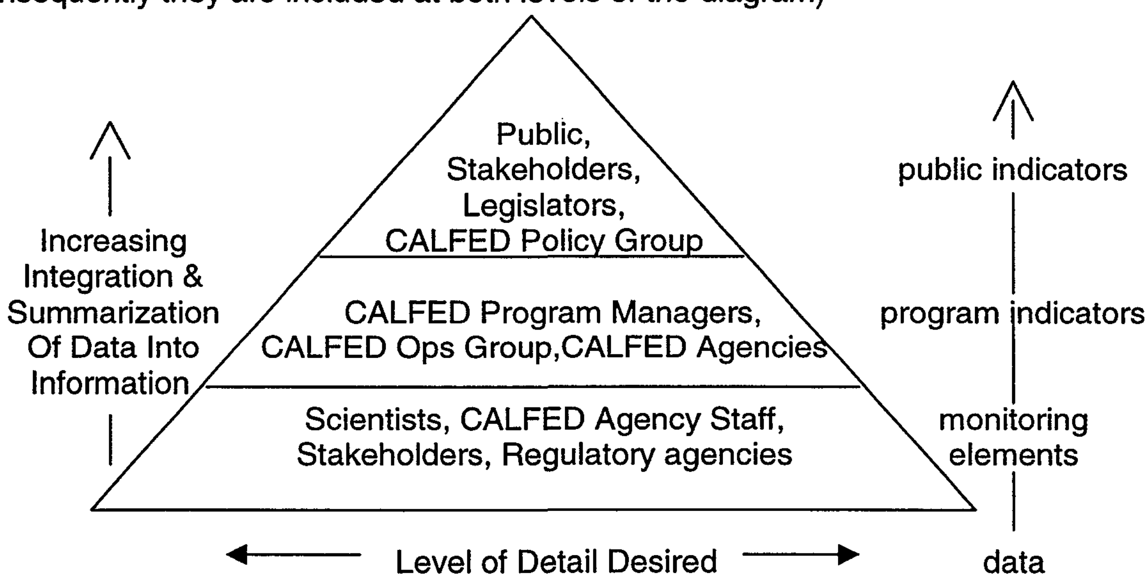
2. The review team needs to primarily include experienced and locally involved specialists who have the local and related history and relationships; however, there exists the challenge of scheduling and commitment of time from these busy individuals. Diverse skills and knowledge are needed, and thus the workgroup needs to expand to have the diversity, interaction and availability of knowledge. A subgroup focus to enhance member interaction may be the best approach to accomplishing the goals of this type of workgroup. Experience from outside the region would be useful to further enhance workgroup evaluations.
3. The important process of reviewing data/conclusions needs to be developed to demonstrate (and implement) how feedback on funding from interested parties and eventually to decision makers will be accomplished.
4. The request/need for monitoring and research information from projects funded by different sources needs better coordination and cooperation, including working through any differences in agency goals and beliefs. This need for coordinated requests also applies to permitting and otherwise-involved agencies and organizations (ESA consultation, etc).
5. The protocols/methods obtained through these early Category III projects should serve as a basis (in conjunction with other available information) for developing standardized protocols for projects.

VI. DATA MANAGEMENT, ASSESSMENT, AND REPORTING

I. INTRODUCTION

<u>Audience for CMARP Reports</u>
CMARP must meet the information needs of a wide and diverse set of people including CALFED Program Managers, the CALFED Policy Group, the CALFED Ops Group, CALFED Agencies, Scientists, Stakeholders, Legislative Staff, and the public. In general the level of detail desired by each group is expected to be different as shown in Figure 1. The process, therefore, must be both robust and flexible to address these diverse needs.

Figure 1. Level of Detail Desired by Different Audiences of CMARP Information and Reports
(Note: While some stakeholders are expected to be interested mainly in basic summarized information about the system, other stakeholders are involved either in the actual collection of data or are very interested in information at all levels of the system. Consequently they are included at both levels of the diagram)



<u>Information needs of the three groups</u>
The anticipated needs of each level of the triangle are summarized below.

The Public, Stakeholders, Legislators and the CALFED Policy Group (top of the triangle) are expected to be interested in questions about the "big picture" and less concerned with the details of monitoring and research. Primarily this group's information needs are anticipated to be:

- what actions has CALFED taken
- are CALFED program goals and objectives being met
- how are indicators of ecosystem health, water quality, water supply reliability, and levee system integrity doing

- what new issues have arisen
- what information has been learned that impacts Stage II implementation decisions
- is the money being spent effectively
- how does it affect the individual person
- where can more detailed information be gotten,
- how can concerns be made known.

Some of the needs of this group will have to be addressed through a joint effort between CALFED common programs and CMARP – for example, in a joint annual report.

In addition to the above list, CALFED Program Managers, CALFED Ops Group and CALFED agencies (middle of the triangle) need much more information on which to make their decisions. Their additional information needs are anticipated to be:

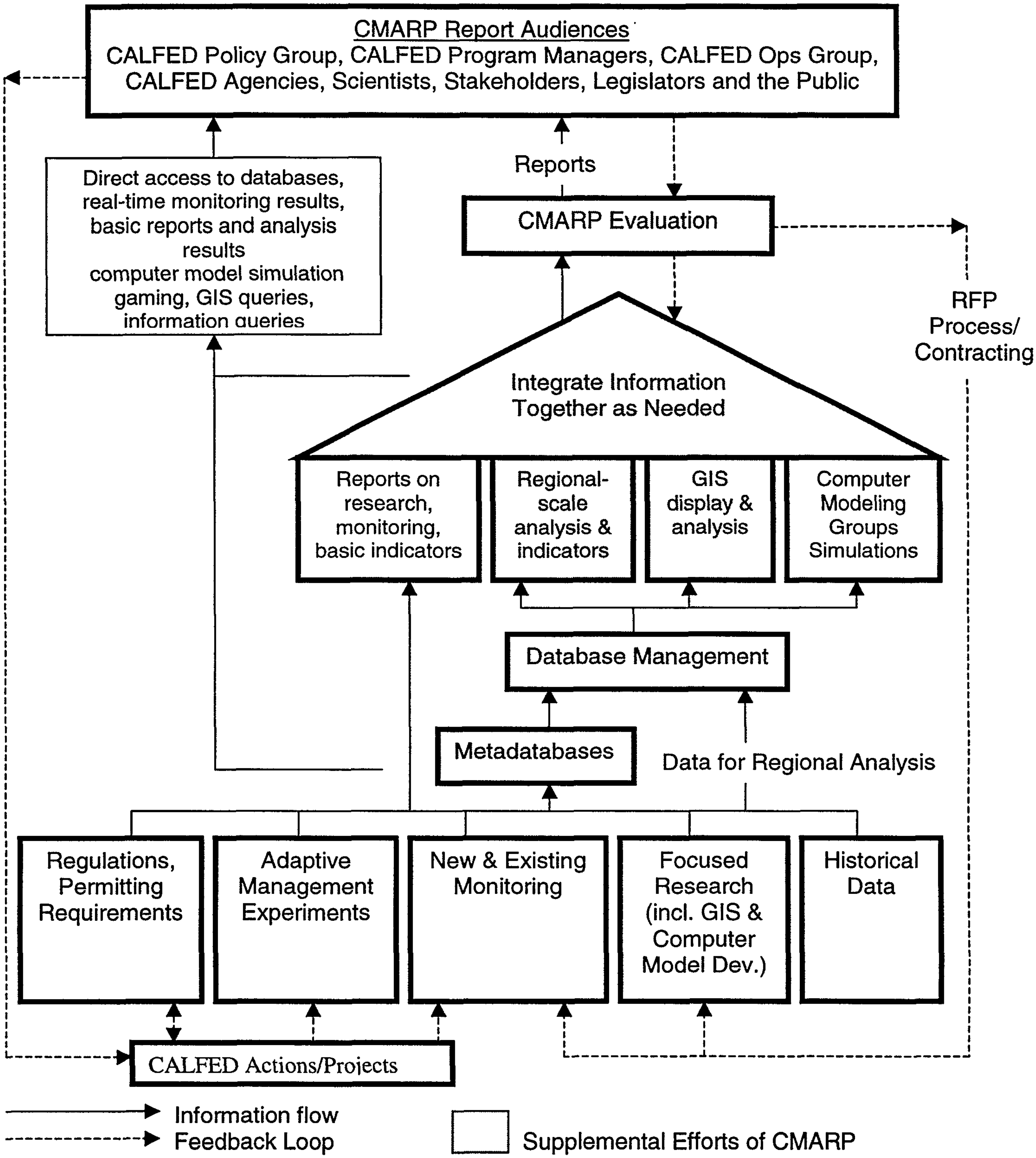
- specific information to base decisions upon
- whether individual CALFED project/action goals and objectives being met
- the status of those factors that influence indicators of valued system components
- what adaptive management actions could be used to improve knowledge of the system
- what uncertainties for managers have been removed through research
- what level of confidence is attached to information and results
- whether compliance and mitigation regulations are being met
- computer models and geographic information system (GIS) as tools for decision-making, and
- a forum to communicate with scientists.

Scientists, agency staff, and some stakeholders are at the base of the triangle and work with very detailed information. This group's needs are anticipated to be:

- to have research and monitoring results published in peer review journals rather than only in "grey" literature, i.e. technical reports.
- general access to data, metadata and reports,
- increased communication and collaboration with other researchers, stakeholders, and agency staff, and
- a forum to communicate with managers.

The steps for meeting the information needs of these groups include gathering of information, quality assurance, analysis and integration, and reporting. Figure 2 provides a detailed conceptual model illustrating 1) the steps involved in collecting the different information involved and integrating them for decision-makers, 2) the feedback loop between CALFED and CMARP, and 3) the feedback loop within CMARP as new research and monitoring needs are identified and acted upon.

Figure 2. Conceptual Model of Information Flow and Feedback Loops between CMARP and CALFED.



Data Assessment and Reporting Guiding Principles

To fulfill the objectives described above as effectively and efficiently as possible, the following guiding principles are recommended. CMARP should:

1) coordinate closely with CALFED program managers and agencies in order to be responsive to their scientific information needs.
2) use existing monitoring programs to meet CALFED needs whenever possible.
3) focus on having any new analyses that are needed for CALFED be conducted by the researchers or agencies actually collecting the data, to the extent feasible. This may require additional funding by CALFED. If the original researchers are not able to do the additional analyses needed, then they may be conducted under the direction of CALFED science staff, in collaboration with the original researchers.
4) strongly encourage publication of research, monitoring, and project results in peer-reviewed literature.
5) make every effort to be an unencumbered channel of information flow between scientists and managers with strong effort made to avoid changes in purpose or content of reports and figures as they travel from scientists to managers. This will require close collaboration and feedback between CMARP and the researchers involved.
6) act as a communication bridge between scientists and managers -- working to get the information produced by scientists into the hands of managers in an understandable form, and working to help scientists better understand the needs of managers.

This chapter combines the products of CMARP's Data Management Work Group and the Data Assessment and Reporting Team into a single description of the overall process of data management, assessment and reporting. The remainder of the chapter is organized under the following headings: Information Gathering, CMARP Quality Assurance, Analysis & Integration, Reporting, and Examples. The chapter focuses on the various tasks that need to be accomplished and leaves the discussion of who will accomplish these tasks to the next chapter – Institutional Structure. A further discussion on early implementation is found in chapter VIII.

II. INFORMATION GATHERING

An important function of data management, assessment and reporting is facilitating the process of getting the overwhelming amount of information currently being generated about the CALFED Bay-Delta system into the hands of decision-makers. This involves compiling the results from monitoring of indicators, research programs, regional monitoring analyses, real-time monitoring data, permitting and regulation requirements, GIS efforts, and computer modeling efforts and delivering it to decision-makers in a manner that is accessible, timely and understandable.

The types of information that will be gathered from monitoring programs and research projects fall into three general categories: reports, metadata, and data.

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Reports and Information Tracking
As stated under the guiding principles, CMARP will be using information from existing monitoring programs and research whenever possible. This will involve coordinating with existing monitoring program managers to get copies of their reports and facilitate getting those reports into the hands of CALFED decision-makers as quickly as possible. To keep the large amount of material involved organized, a systematic process for tracking, organizing and querying the information, reports, and data sets from CALFED-related research and monitoring programs will be created.

Create metadatabases of monitoring programs, research efforts and computer models
The amount of monitoring, research and computer modeling efforts being conducted in the CALFED Bay-Delta system is so large it is difficult for any one person to know about even a fraction of the information available. Over 600 monitoring programs have been identified. To avoid duplication of effort, reduce the costs involved in providing information to CALFED, and improve coordination among agencies and researchers, CMARP is building a metadatabase of monitoring programs in the CALFED Bay-Delta system and associated watersheds (see Chapter __). This database forms the basis for determining what data are available and how they could contribute to broader CALFED goals.

Three additional metadatabases are also recommended for development involving: 1) larger research efforts related to CALFED's objectives, 2) computer modeling efforts related to CALFED's objectives, and 3) GIS efforts related to CALFED. These metadatabases will be accessible to the public via the CALFED/CMARP web page.

Additionally a comprehensive list of scientists, agency staff, stakeholders, managers, etc. involved with CALFED will be developed into a queryable database. The Institutional Structure Peer Review process also calls for the development of a database of experts who can be contacted by CMARP to conduct peer review evaluations on reports, projects, etc..

CMARP Database Management
Data management is important to all aspects of the CMARP data collection and dissemination processes. Ultimately, CMARP must make data/information readily accessible to CALFED Bay/Delta and agency staff and stakeholders. Data also need to be regularly updated, meeting different program reporting timelines to allow information to be related among programs in time to modify adaptive management strategies.

An integrated database system allows for comprehensive data access that permits broad access to biological, water quality, terrestrial, hydrodynamic and physical field data from the Bay/Delta and its watershed. It will also allow geo-referencing, and common units of measuring and labeling data. The intent of the CMARP database project is not to duplicate or replace the efforts of any entity involved, but to provide a comprehensive, integrated source of data for scientists and decision-makers.

The proposed solution is a Relational Database Management System (RDBMS) that will allow individual data providers to manage their own data locally, while contributing to a larger comprehensive database. Each data provider will have control over its own data, which will be fully protected within the data management structure. Only the data provider will have permission to change its own data. Data will be uploaded with stringent QA/QC, and data providers will be notified of problems.

One problem is the ability to make monitoring data available quickly. Because so many data providers will contribute data to CMARP, an important advantage is the efficiency of the proposed RDBMS. It will allow data providers to locally manage their own data and instantly upload it to a comprehensive database where it will be normalized, standardized and made available to users for reports and applications. Yet another advantage is the wide use of the data. It will be used by multiple agencies and stakeholders, such as DFG, CUWA, SFEI and IEP. This system will be an invaluable resource to CMARP.

A Bay/Delta and Tributaries (BDT) Relational Database Management System (RDBMS) is being developed by IEP, SRWD and CVPIA/CAMP in conjunction with CUWA. The system is being implemented for the Spring Run Chinook Salmon Program. By using this RDBMS as a prototype, CMARP can quickly and efficiently provide a data management tool that can be evaluated by CMARP data providers, data users, agency staffs, and stakeholder groups. The CMARP Data Management Work Group (DMWG) will formulate user surveys that will allow us to gather information on the efficacy of the system directly from users. This will include groups using the system to supply information to GIS, data analysis software and other data-driven applications. Data providers will manage their own data locally, equipped with customized software that will dynamically update the comprehensive server. Groups that provide data to the BDT will be interviewed to determine how the local databases are managed. Evaluating a working system will allow CMARP to effectively and proactively evaluate how this type of system will address its needs, without relying on theoretical analysis.

- <u>Technical Feasibility</u>

Relational Database Management Systems and the World Wide Web are easily accessible technologies, and training is readily available. Most users are already using Internet browsers, such as Netscape Navigator/ Communicator, and Internet Explorer. The databases set for local uses have an easy-to-use, customizable graphical user interface (GUI), that is easily learned. CMARP can take advantage of the work already completed by using the BDT RDBMS structure and modifying it for use with CMARP monitoring data, providers and users. This RDBMS is currently being implemented for Spring Run Chinook Salmon, and evaluations of this system will be based on actual use and feedback from data providers and users.

- <u>Political Feasibility</u>

The BDT RDBMS has already been implemented across various agencies and stakeholder groups, showing that this solution is politically feasible. Individual agencies will be able to manage their own data locally, as well as upload to a comprehensive database under strict QA/QC guidelines. This protects referential integrity as well as the integrity of the data itself. The RDBMS solution also provides a way for various agencies to not only contribute data, but also access diverse monitoring data for reporting, analysis, and facilitation of adaptive management strategies.

A more detailed description of the proposed CMARP Relational Database Management System can be found in the CMARP Data Management Work Group Appendix ________.

III. CMARP QUALITY ASSURANCE

The quality of the information used by CMARP depends on two different levels of focus: 1) the quality of the data collection and analysis by the individual programs and 2) the integration of data from several monitoring programs for regional analysis efforts.

The quality of data collection and analysis by individual programs can be divided into three basic areas: a) how closely CALFED's needs match the needs and objectives of the individual monitoring program, b) the adequacy of the quality assurance/quality control plan of the individual monitoring program, and c) the effectiveness and efficiency of the monitoring plan design in meeting its stated goals and objectives.

Integration of data from multiple monitoring programs for regional analysis efforts will result in three basic types of problems: d) dissimilar units, basic error-checking, resolving outliers, etc.; e) differences in sampling methodology, laboratory protocols, equipment, experience of personnel, and nomenclature; and f) gaps in space, time and frequency among current monitoring efforts.

These six issues (a through f) are discussed further in the Data Assessment and Reporting Team Appendix ______

The final issue, which will assurance quality of the data collection and analysis used by CMARP, is external review, particularly external peer review and publication in peer-reviewed literature. CMARP will place a strong emphasis on publication of all results in peer-reviewed literature and will use this standard in all its activities. The process of external review and peer review is further discussed in Chapter 7 – Institutional Structure.

It is important to note that CALFED and CMARP can only make requests of existing monitoring programs to be able to share their data and/or request changes in the existing monitoring design. It is hoped that existing monitoring programs will be willing to assist CALFED in meeting its needs, in exchange for being able to be part of a regionally coordinated monitoring effort, and have better exchange of information and communication among researchers, and also if CALFED covers any additional costs that are incurred. Obviously each program's own needs and objectives are expected to take precedence over CALFED needs.

III. ANALYSIS AND INTEGRATION

CMARP will assist with assessing the current status and trends of indicators, improving understanding of system functioning, assessing the effect of management actions, and providing information to help determine and prioritize future management actions. The analysis of indicators and adaptive management experiments are discussed further below. The role of geographic information systems (GIS), computer modeling, comparative risk analysis and event probability analysis are discussed in the Data Assessment and Reporting Team Appendix.

<u>Analysis of Indicators</u>

- <u>General analysis of indicators</u>

Much of the information regarding CALFED indicators can already be gleaned from existing agency reports and databases. Where such information is sufficient for CALFED purposes, CMARP's role will involve facilitating the process of getting the information to decision-makers and making the information generally available. In those cases where the current analysis and reporting mechanisms are inadequate, CMARP will focus on arranging for the additional analysis and reporting to be conducted, preferably by those researchers actually involved in collecting the information whenever possible.

- <u>Development of Baselines</u>

In order to be able to gain sufficient understanding of the the Bay-Delta System upon which to make decisions and to evaluate the effect of CALFED actions once initiated during Stage I Implementation, it is important that baselines for indicators be developed as soon as possible using historical information and data monitored through the year 2000.

- <u>Regional analysis across wide spatial and temporal scales</u>

An important function of CMARP is the coordination of regional monitoring efforts among programs so that new analyses can be conducted across wide spatial and temporal scales. Spatio-temporal statistical methods will be used to examine field data taken at approximately regular intervals at spatially distributed sampling stations. The major methods look at the correlation structure of the data over time (as in conventional time-series analyses) and space, and in a few cases, over both. Studies of this kind have already been used in IEP-related studies to refine the information needs of water quality nutrient, and plankton sampling programs (i.e. what are the tradeoffs between the number of sites and the frequency of sampling in terms of being able to detect certain kinds of changes). Correlations among causative factors (e.g., effects of nutrients, temperature and light on productivity) can then sometimes be analyzed within the constraints of spatial variability in the data.

An example of how pulling together information on a regional scale is useful for decision-making is the process the CALFED Ops Group uses to anticipate salmon outmigration and reduce entrainment at the pumping facilities. This process is described briefly in Example A at the end of this chapter.

- Develop correlations and hypotheses about cause-effect relationships.

Various areas of uncertainty exist about the San Francisco Bay-Delta, for example how the ecosystem functions and reacts to change or how water transfers affect neighboring areas. A great deal of data is being collected throughout the San Francisco Bay-Delta and its associated watershed, but the agencies collecting this data often do not have the time or the resources to further analyze this data beyond the scope of their program's objectives. It is expected that some of this data can be combined and analyzed to identify possible cause-effect hypotheses which can then be used as a foundation for identifying priority research needs. One function of CMARP will be to sort through the numerous uncertainties identified by the CMARP workteams and determine those addressable with existing information and arrange for these analyses to be conducted. An additional task is to continue monitoring currently established correlations for changes which can indicate shifts in the functioning of the system. Example B at the end of this chapter shows such a shift. In this example mysids are weakly correlated with the position of X2 until the late 1980's when clam density began increasing. In this case the introduction of a new species changed the strength of existing correlations in the system.

Adaptive Management Experiments

The CALFED program has committed to a process of adaptive management which will involve adaptive management experiments. This will likely involve pilot projects to test hypotheses of system functioning and manipulation of the system to determine cause-effect relationships (for example, how altering flow rates into the delta affect salmon migration). CMARP's role will be to organize analysis and reporting of the results of these, preferably by those researchers and agency staff most directly involved. CMARP will also work to facilitate communication between researchers and decision-makers to identify where adaptive management can be effectively applied and to design experiments that will yield as much information as possible.

V. REPORTING

Characteristics of reporting system

CMARP's reporting role is to 1) make this information accessible to all interested CALFED participants, 2) sift through this information to the information requested by decision-makers and facilitate getting the information to them, 3) facilitate the process of integrating and summarizing the information to the extent desired by decision-makers and the public, 4) ensure presentation in a format that is clear and understandable to decision-makers, and 5) facilitate understanding of the science involved by managers and facilitate understanding of management needs by scientists.

The reporting system will be characterized by transparency, accessibility, objectivity, reliability, high quality and rapid reporting of results.

Accessibility of information to all interested parties will be maintained through the generation of reports, through public quarterly technical meetings and an annual science conference, through a process for querying information and through intensive use of web page technology.

Types and Frequency of Reports
The types and frequency of reports will be determined by the needs of the public and of CALFED program managers. Each of the CALFED Programs is different in nature and purpose and has differing reporting needs. These needs will be more completely understood as the CALFED process moves forward. Reporting needs are expected to range greatly in frequency and content including near-real time monitoring, monthly reports, quarterly reports, annual reports and likely program reviews every 2-3 years. In addition reporting will also involve papers published in peer-reviewed journals, fact sheets, reports responding to information queries, and web page reporting.

The reporting needs of the public and stakeholders will be met through annual reports, web page reporting, fact sheets, and quarterly technical meetings. The needs of the CALFED program managers and the CALFED Ops group are expected to be met through real-time monitoring information, monthly and/or quarterly reports, information and analysis queries, an ability to conduct what-if scenarios with computer models and GIS models, and through an annual science conference. The needs of scientists and agency staff are expected to be met with publication of research and monitoring results, computer models and conceptual models in peer-reviewed journals, access to metadatabases and database information via the web-page, annual science conference, and frequent issue-based workshops. Regulatory agencies will receive necessary reports involving compliance and mitigation monitoring.

In addition, all parties will have access to information available on the web page such as the CMARP database, metadatabases, indicator status reports, etc.

- Annual Reports

An annual report will be produced directed primarily towards the public, stakeholders and legislative staff. It is recommended that the annual report be a joint effort between CALFED and CMARP and include contents reflecting the activities of each. The recommended content of the annual report includes: 1) summary of CALFED actions taken during the year, 2) status of indicators for valued system components and their influencing factors, 3) status of CALFED program goals and objectives, 4) highlights of what has been learned, both positive and negative, during the year, 5) highlights from research projects completed and underway, and 6) a fiscal summary. Agreement on the contents of the Annual Report must be reached with the public and stakeholder groups, preferably through open-forum meetings. The recommended delivery date of the Annual Report is the third week of April (approximately the same time as the IEP spring newsletter, which includes indicators that should also be included in the Annual Report). The first annual report will be delivered on April 20, 2001.

- Annual Science Conference

An annual science conference will bring CALFED Program Managers, scientists, and agency staff together. Various research efforts can be briefly reported, the status of indicators discussed, and new issues raised. This conference will provide information for the annual report. The description of the Annual Science Conference is discussed further in Chapter 7 – Institutional Structure.

- Real-Time Monitoring Reporting

CMARP expects to use some real-time monitoring reporting. Real-time monitoring refers to the near-immediate reporting of data usually with a delay between collection and reporting ranging from a day to a few weeks depending on the type of data. Although such data typically is "raw" and has often gone through very little quality control, the information is useful for compliance monitoring and for early detection of changes and problems so program managers can respond quickly or more focused monitoring or research can be initiated.

In particular, the CALFED Ops Group already makes effective use of real-time monitoring, using data that relates stream-flow, turbidity, and the location of species of concern in the Delta to make decisions about pumping Delta exports. In such a case, CMARP's role will be to not interfere with a decision support system that is already working well, but instead to attempt to facilitate the process of getting information to decision-makers, where needed, and to increase access of this information to other CALFED program managers.

The Water Quality Program anticipates needing monthly status reports, which will probably include a brief 3- to 4-page summary of the status of water quality indicators, and monitoring elements. Each of the CALFED programs involved in water management (Storage, Conveyance, Water Transfers, Water Use Efficiency) will need regular access to information such as water flow-rates, height (stage), water quality and ground-water levels.

Because real-time monitoring can be expensive, CMARP will be coordinating reporting of results from existing real-time monitoring efforts. Initiating new real-time monitoring efforts will be considered only after the considerations of purpose, expense, and diminished data-quality risk have been weighed.

- Quarterly Technical Meetings & Bulletin

Frequent technical workshops or meetings are recommended, possibly on a quarterly basis, during which CALFED program managers, CMARP, scientists and stakeholders can meet for 1) updates on progress, 2) explanation of what the data reveal, and 3) discussion of new issues. A quarterly bulletin will be issued for the purpose of this workshop.

- Information Query Response

One important purpose of data analysis and reporting is to assemble the to be easily queried by managers, scientists, etc. In addition to having information on the web, CMARP will also respond directly to queries for information from program managers, scientists, agency staff and stakeholders. This process will be developed further in the future as the specific needs of each of the CALFED programs becomes clear and

CMARP continues to evolve into the future. Obviously the ability to answer queries efficiently and quickly will depend on the amount of staff time available and the amount of time and effort needed to create an accessible and frequently updated web page.

Some queries will be simple requests for information; for example the Delta Levees Program will likely need to be able to query the status of delta-levee monitoring on a regular basis. Other requests for information will require some additional analysis and work involved, such as a requests for information relating to a new invasive species (e.g. mitten crab collection at the south-delta pumps). CMARP's role will be to channel the request for this information to those researchers and agency staff with the best ability to answer the question and to facilitate getting a timely response to decision-makers.

- Web Page Reporting

CMARP will make intensive use of web-page technology to make information available to all interested parties. The CMARP web page is anticipated to include: 1) current status of public indicators, program manager level indicators, and additional monitoring elements of special interest to scientists, agencies and stakeholders; 2) access to metadatabase information compiled through the CALFED process; 3) access to the CMARP monitoring and research database, and 4) copies of annual reports, quarterly and monthly status reports and journal articles related to CMARP.

Creating and maintaining this web page will require planning and investment in staff and training from the beginning. In the long run, this investment will greatly reduce the amount of staff time spent answering queries for basic information and will greatly increase access of information to all interested parties.

VI. EXAMPLES

A. An Example of the CALFED Operations Group Decision-Making Process

The CALFED Operations Group has developed a hierarchical consensus-driven process for incorporating current environmental information quickly into decisions regarding operations of the Central Valley Project (CVP) and the State Water Project (SWP). This process is depicted in Figure 6 and is summarized below. A more detailed description of the process provided by Zachary Hymanson is in the Data Assessment and Reporting Team Appendix.

To accomplish this process the CALFED Ops Group established the "No-Name Group" which keeps all involved agencies and interested parties informed about the take of environmentally threatened or endangered listed species and other related issues that affect CVP/SWP operations. Sub-groups have been created in turn which analyze data and propose operation actions regarding issues such as winter-run chinook salmon, delta smelt, real-time fish monitoring, etc.

One such sub-group is called the Data Assessment Team (DAT) which consists of biologists from CALFED agencies and stakeholder group and CVP/SWP operators.

This group compiles and interprets fishery-related data and disseminates the interpreted information to the CALFED Ops Group. DAT has been involved with evaluating spring-run Chinook salmon. Data are compiled from 13 sites. The DAT team assesses the data for 2 indicators of the start of the run: direct capture of fish and/or abrupt changes in river flow or water clarity which are often associated with the beginning of the downward movement of salmon. When an indicator is found, the DAT team assesses the situation and makes recommendations within 24 hours for the adjustment of CVP/SWP operations. The DAT Team also then notifies the No-Name Group Chair, CVP/SWP Operators, and the co-chairs of the CALFED Ops Group.

Figure 3 shows a simple conceptual model relating water pumping in the south Delta, water supply reliability and health of the salmon. Figure 4 shows the decision process of the CALFED Ops Group. Figure 5 shows the relationship between winter-run salmon salvage, river flow rates, delta outflow rates and time of year.

Figure 3. Conceptual model of relationship between water pumping in the south Delta, water supply reliability and health of the salmon population

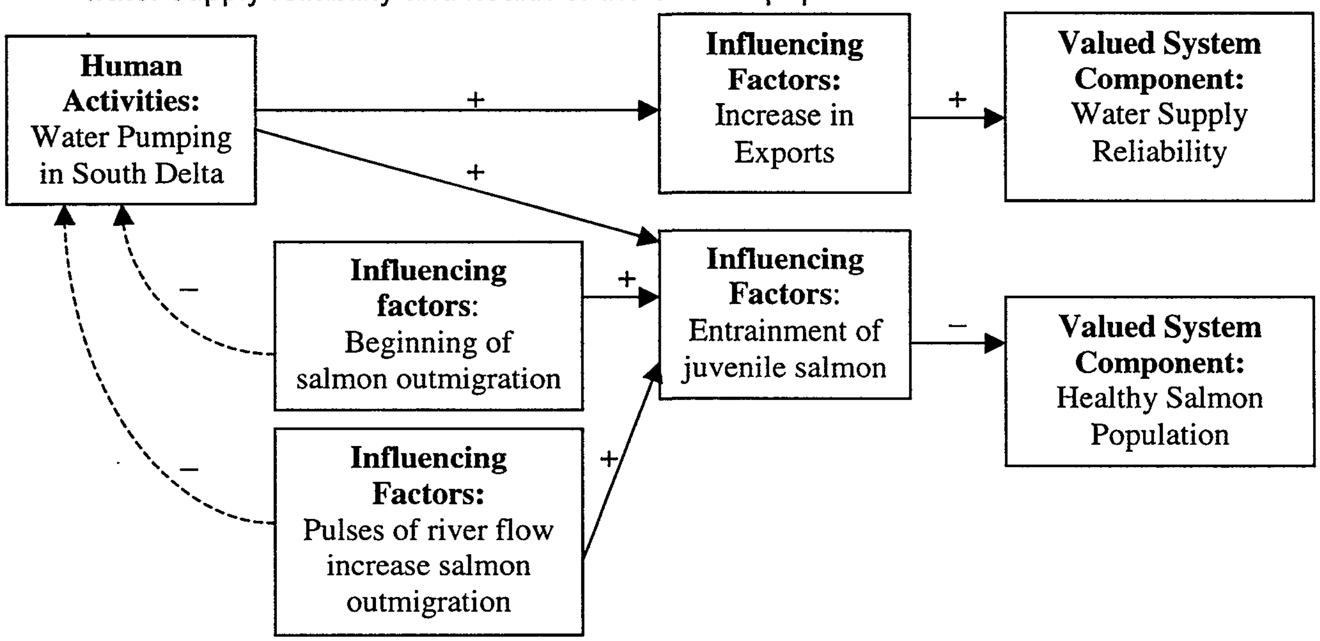

Figure 4. CALFED Ops Group Decision Process

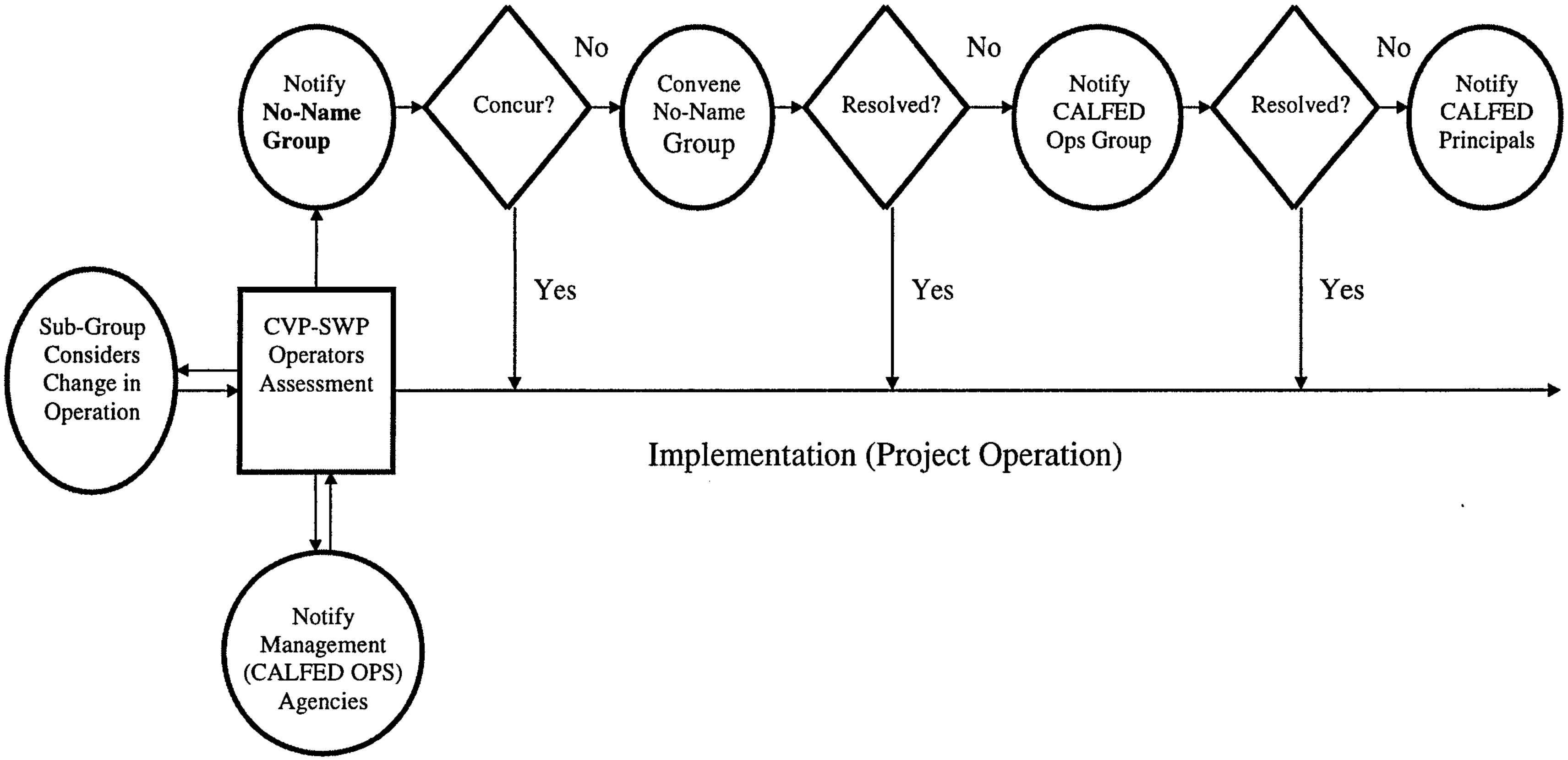

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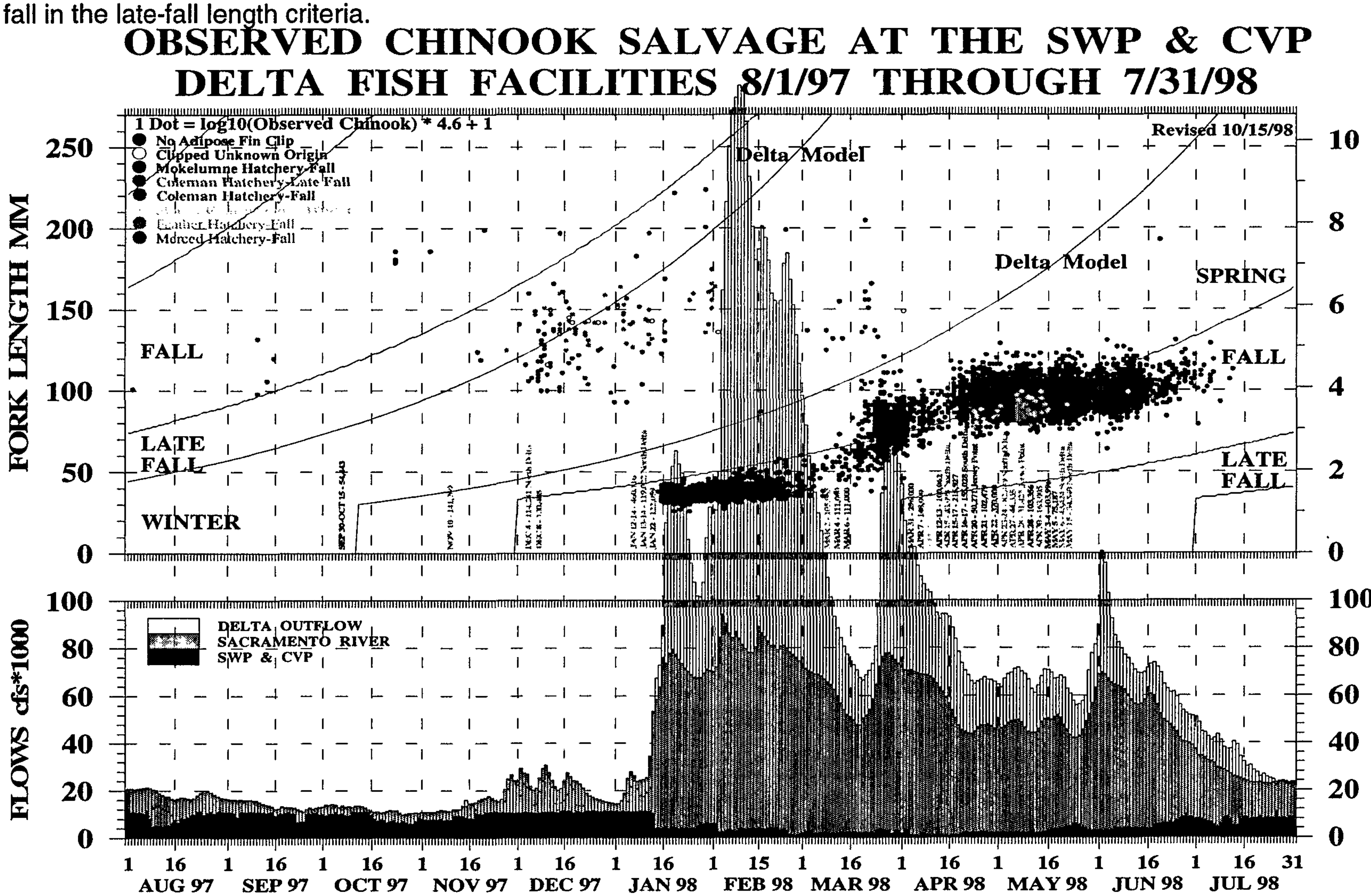
Figure 5. Plot of winter-run Chinook Salmon incidental take at the SWP & CVP Delta Fish Facilities from 8/1/97 through 7/31/98 created by Sheila Greene, Dept. of Water Resources. In addition to showing Chinook salmon salvage, the plot relates salmon salvage to flows and exports and shows the timing between hatchery releases and recapture at the facilities. The plot also shows the length criteria the hatchery fish fall in. For example late-fall chinook are released from Coleman hatchery from November to January. The plot shows how many of the recovered late-fall hatchery fish actually fall in the late-fall length criteria.



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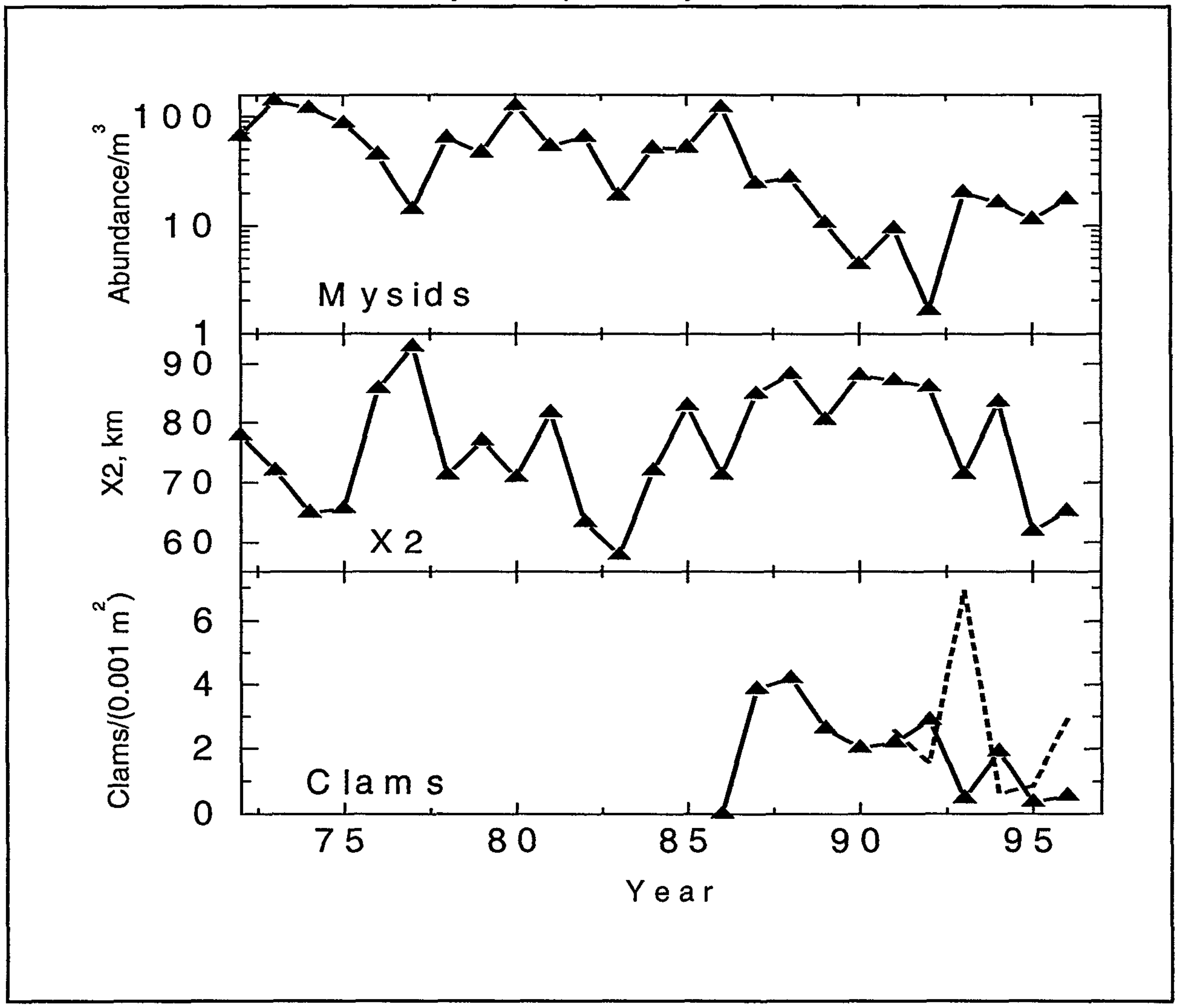
B. Correlating Mysid abundance, X2 Position, and Clam density

Developing correlations among different types of data are useful in discerning possible cause-effect relations, which then can be further researched through an RFP process. In addition such correlations are important for discerning new problems that are developing. For example, the following figure shows that mysids were weakly correlated with X2 position until the late 1980's when clam density began increasing. This emphasizes that the San Francisco Bay-Delta ecosystem is a constantly changing system. Coordination between managers and researchers is needed to rapidly identify such changing relationships and incorporate them into the decision-making process.

Figure 6.Time series for mysids (*Neomysis* and *Acanthomysis*) (top), X2 (middle), and clams (*Potamocorbula amurensis*), annual means for sampling seasons for stations in Grizzly Bay (triangles) and San Pablo Bay (dashed line). Mysid abundance is weakly related to X2, but evidently affected by clams: the lowest abundances of mysids were post-clam, and even when flow increased after the drought in the 1980's-90's, mysid abundance failed to recover much beyond its previously lowest value.



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Chapter VII. INSTITUTIONAL STRUCTURE TO IMPLEMENT CMARP

INTRODUCTION

The Phase one report states that the Steering Committee will develop recommendations for creating an institutional structure to implement the CMARP over the long-term. These recommendations would emphasize flexibility. They would be made after review of the strengths and weaknesses of large scale environmental monitoring programs both locally and around the country, after consulting with the agencies and stakeholders involved in CALFED and the organizations that would be expected to participate as partners within CMARP. While we have made good progress in reviewing large-scale environmental monitoring programs and in consulting with participating agencies, partner agencies and stakeholders, we have not completed these external evaluation and consultation processes. Thus, the recommendations of this Chapter are considered preliminary.

The characteristics or attributes CMARP ought to display and the functions the structure ought to perform are listed. We describe the elements needed of a management structure to ensure that the functions are carried out and the processes that the structure will need to implement to ensure that the attributes are obtained. Largely because the long-term arrangements for the implementation of the CALFED program have not yet been determined, CMARP participants believe that the final form the CMARP Institutional Structure ought to take cannot be resolved at this time. Issues upon which additional input would be helpful have been identified.

Because of the uncertainty about the long-term CALFED Institutional Structure, this Chapter uses several terms, which need definition. We presume that there will be some CALFED sanctioned body to which the CMARP will report and from which it will receive direction and funding authorization. This body might be a continuation of the current policy group, a newly comprised Board, an existing agency or a new organization. We refer to this institution as the <u>Decision-making Body</u>. We refer to the long-term monitoring, assessment and research program as <u>CMARP</u>. Use of this term does NOT imply that it is organized and governed in the same fashion as the CMARP Steering Committee used for Phase II. We use the term <u>Monitoring, Assessment and Research Organization (MARO)</u> loosely to cover any possible arrangement from an interagency working group to a newly formed Institute; it is the organization that will be responsible for implementing CMARP. <u>The CMARP Team</u> refers to all scientists and other personnel working on the CMARP, including those formally within the Monitoring, Assessment and Research Organization, and in the larger body of CMARP participants and contractors.

ATTRIBUTES of a CMARP INSTITUTIONAL STRUCTURE

Discussions among the workgroup participants and with those interviewed led to the conclusion that certain principles or primary sets of attributes ought to underlay all deliberations on institutional structure for the program. Any recommended institutional structure for CMARP must address these principles.

RESPONSIVENESS TO MANAGEMENT NEEDS--The primary purpose of CMARP is to provide the information and scientific interpretations and advice necessary for CALFED to fully implement its preferred alternative, including the common programs, and for the public and government agencies to evaluate the success of CALFED. The ability of the program to provide the kind of information needed by managers as they move forward through the decision process is, therefore, paramount. The types of management needs to which the CMARP must respond include:

- Documenting compliance with regulatory standards.
- Detecting and reporting trends in environmental condition.
- Measuring CALFED program performance.
- Providing timely information for decisions.
- Collaborating with management to execute active adaptive management.

SCIENTIFIC QUALITY--The importance and cost of the decisions to be made in the CALFED process and the demands of the adaptive management require that these be based upon the best scientific information that can be made available. CALFED managers need to be assured that the scientific work they are funding, and upon which they will be relying, is of the highest quality possible. Quality will depend upon independence of CMARP from political pressures, commitment to long-term monitoring, assessment and research, and the competence and credibility of the scientific staff.

- Scientific competence and credibility achieved through publication of results in peer-reviewed scientific journals.
- Scientific breadth and depth resulting from a broad mixture of disciplines and expertise represented in the Monitoring, Assessment and Research Organization and the CMARP Team.
- Independence such that CMARP scientists have the ability to determine how best to do their work and be free of attempts to influence their findings, achieved at least in part by extensive use of external scientific review.
- Commitment to long-term monitoring, assessment and research to reduce uncertainty.

ACCOUNTABILITY--Accountability encompasses responsiveness and quality, but also includes the concepts of cost-effectiveness, transparency of process and participation. There appears to be strong support for a substantial increase in the funding over that now allotted for monitoring, assessment and research. But with additional funding is an increased sensitivity to accountability. Accountability requires:

- Easy access to all of the data and information upon which decisions are based.
- Collaboration among scientists, stakeholders and resource managers.
- An open, consistently applied and transparent process for setting program priorities and making funding decisions.
- Cost-effectiveness achieved through building upon existing programs and through employing competitive solicitation processes.

The workgroup recognizes that many of these attributes stand in opposition to each other. For example, independence implies an absence of control while responsiveness requires a degree of control over program decisions. Over-emphasis on cost-effectiveness may threaten commitment to scientific excellence. Responding to urgent management needs could threaten the commitment to long-term monitoring. The greatest challenge involved in the implementation of CMARP will be in achieving the appropriate balance among these competing principles.

FUNCTIONS of the CMARP INSTITUTIONAL STRUCTURE

Perhaps the first question to address in considering an institutional structure for implementation of CMARP is what it is that CMARP must do for CALFED. The CALFED Decision-making Body will need information to answer short-term questions before proceeding with the staged decision-making process, and measurement of the long-term conditions in the Bay-Delta and associated performance measures to determine whether individual projects initiated by the common programs are successful and whether the problems of the Bay-Delta are being solved. The principle function of CMARP is therefore, to manage the direction of the monitoring, assessment and research program to provide this essential information.

CMARP will also be the scientific arm of CALFED and will be prepared to assist in the design of the adaptive management program. This assistance must come from individuals who understand experimental design and the design of field programs. In addition to analyzing trends, CMARP must be prepared to initiate scientific research, including monitoring, modeling, and data analysis, to determine whether things are changing and what effect the CALFED actions have had. Although this will not always be possible, it should be the idea behind all of the performance assessment.

The functions that the institutional structure created for CMARP must carry out therefore, include the following:

- Designing and directing the monitoring, assessment and research program,
- Collecting, managing and distributing data,
- Analyzing and interpreting data, and reporting the findings,
- Orchestrating external scientific review of projects and programs, and
- Collaborating with management on adaptive management.

We assume that some new core organization or organizations would need to be created, whether through formal or informal means, to serve as the recipient for CALFED funding and to serve as the focal point for accountability. These general functions require that several tasks be carried out by the Monitoring, Assessment and Research Organization (MARO) and some by the broader additional array of organizations that make up the CMARP Team. The Structures and Processes discussed below illustrate by whom and how these functions might be carried out.

ELEMENTS of the INSTITUTIONAL STRUCTURE

We believe that given the need for the functions described above, certain elements of an institutional structure will be needed. The following elements will serve to increase the probability that the Monitoring, Assessment and Research Program will achieve the desired attributes and can fit into any number of structural approaches. These elements collectively would comprise the Monitoring, Assessment and Research Organization (MARO):

1. Science Review Board, advisory to highest Decision-making Body for CALFED
2. A highly visible position of Chief Scientist with direct access to decision-makers.
3. A highly qualified team of scientists and support staff to assist and advise the Chief Scientist, which we refer to as the Technical Evaluation Team.
4. A Science Coordination Team, made up of individuals from the agencies and organizations responsible for implementing major elements of the monitoring, assessment and research program.
5. Partnerships based upon collaborative working relationships between and among Chief Scientist, the Technical Evaluation Team and the agencies and organizations conducting CALFED funded AND non-CALFED-funded environmental monitoring and research which comprise the CMARP Team.

SCIENCE REVIEW BOARD--The Science Review Board will play an important role in guiding the Decision-making Body with regard to its use of science in adaptive management and decision-making. Because science inherently produces uncertain results, often complicated by contentious debate among conflicting interpretations, the Decision-making Body may need assistance in understanding the quality and usefulness of the information upon which they are asked to make decisions. The Science Review Board will help the Decision-making Body make these judgments. The Science Review Board will also assist in using scientific information to evaluate whether the CALFED program is reaching its dual goals of improving water supply and restoring the Bay-Delta ecosystem. It would ask such questions as "Is the condition of the Bay-Delta system improving?" "Is the CALFED program using adaptive management experimentation effectively to reduce uncertainty and improve management?" This level of review addresses not the quality of the scientific program *per se*, but the use of science in the management program.

The development of the Science Review Board needs to provide both for some stability and for turnover and fresh ideas and viewpoints. Staggered terms of 3-5 years would provide this. The Board needs both to be allowed the highest degree of independence, yet be able to work closely and hold the trust and respect of the CALFED Decision-making Body. We would suggest an approach in which professional societies such as the American Fisheries Society, the Estuarine Research Federation, the National Academy of Sciences, the National Science Foundation, or the Wetlands Society make nominations to the Board. The Board should selection new Board members itself; it should be self-renewing. The Decision-making Body should have the power to veto a proposed nominee, but not to make the selection. This leaves the question of the original selection of the Board. The solicitation of an original slate of candidates could be contracted to the National Academy of Sciences or some other well-respected and neutral group of eminent scientists.

Since the primary source of information for the Science Review Board will be the CMARP, judgments on the quality, breadth, and applicability of the work done by CMARP will, to some extent, be a necessary by-product of the Science Review Board's principle role. The Decision-making Body may also, therefore, look to the Science Review Board for assistance in evaluating the quality and effectiveness of the CMARP. Since this exercise will, to a degree, involve evaluation of the talents and judgment of the Chief Scientist and the Science Coordination Team that reports to the Chief Scientist, an arm's length relationship between the Board and the Chief Scientist should be maintained.

<u>CHIEF SCIENTIST</u>--Scientific leadership is a key to the success of the CMARP, and is more important than any other aspect of the organizational structure set up to operate or govern the program. While it is possible that this leadership will emerge from within the agencies and organizations that will be participating in the CMARP, or from a coordinating committee created to guide the CMARP, it is just as likely that it will not. We believe that an endeavor of the magnitude and importance of CMARP must have strong leadership. Providing a position of Chief Scientist will help to ensure that a high level of credibility and accountability are attained. Regardless of the particular arrangement chosen, numerous individuals, agencies and organizations will be involved in the CMARP. Without a central figure with the charge of making the program work and producing results, it will be very difficult to determine where responsibility for problems or deficiencies in the program lies.

This individual will need to have the breadth and depth of understanding of environmental and related sciences to be able to fashion a program that entails all of the subject matter described in other sections of this report. He or she will need to have the credibility and enthusiasm to inspire the confidence of all of the scientific personnel working on the CMARP, whether or not those scientists work directly for him or her. He or she must be able to identify and draw upon the expertise of scientists from around the country as well as those locally to assist in peer review and external review processes. This individual will have to have extraordinary communication skills to be able to understand the needs of decision-makers, relay scientific findings to them in understandable terms, and communicate with public audiences and scientists from a variety of disciplines. He or she must be able to simultaneously speak the truth and maintain the trust and confidence of all of the stakeholders. Finally, he or she must be at least a bit of an iconoclast, and be willing to challenge the paradigms that influence our current understanding of the Bay-Delta system.

The Chief Scientist will report to the head of the agency or organization in which his/her position resides and also directly to the CALFED Decision-making Body. Duties of the Chief Scientist will include the following:

1. Be responsible for the overall direction and quality of the monitoring, assessment and research program.
2. Assemble and direct a *Technical Evaluation Team* that can provide the type of analysis and interpretation of monitoring information discussed in the DART report.
3. Chair a *Science Coordination Team* designed to keep all of the agencies and organizations that implement elements of the program working collaboratively.
4. Identify (through communication with the Decision-making Body, Science Review Board, Stakeholder Advisory Committee, etc.) the management issues that need to be addressed through the CMARP.
5. Produce an annual work plan of monitoring, assessment and research to be approved by the Decision-making Body.
6. Ensure that the external review functions are carried out, supported, and heeded.
7. Convene an Annual Science Conference.

The Chief Scientist has the ancillary duty of interacting with the regulatory agencies. There is a feedback loop with the regulatory agencies such that regulatory monitoring might be improved, and the information produced feeds and affects the regulatory process.

<u>TECHNICAL EVALUATION TEAM</u>--A team of individuals to assist the Chief Scientist as a core staff needs to be assembled. The Chief Scientist should have a fairly free hand (subject, of course to budgetary limitations) in assembling this team; that is, he or she ought to be able to 'recruit' from within agencies (as well as from external organizations) but not have agency personnel assigned to the team by the agency. This team would advise and assist the Chief Scientist in developing the annual work plan to address monitoring, assessment and research needs, help to develop and lead research programs in conjunction with extra-mural researchers, form working teams to operate monitoring programs which are largely agency-conducted, nurture partnerships with scientists in other research organizations, critically review and analyze CALFED and non-CALFED funded monitoring program data, work with data generators to interpret and produce publishable findings based on current data, and report periodically and as needed to the Decision-making Body and the public.

We envision this team to consist of a number of highly qualified scientists representing a broad array of expertise in the environmental sciences. It would be desirable to have a mix of individuals that includes some that have extensive experience within the Bay-Delta system and that have developed relevant expertise working in other systems, and some that are well-established in their fields and others who are at the beginning of their careers. One way to ensure that a continual stream of new thinking and approaches flows into the Technical Evaluation Team would be to assign a number of time-limited postdoctoral positions to the team. The scientific staff would also need various forms of support, including technical, data management, graphics and administrative.

SCIENCE COORDINATION TEAM--The agencies and organizations that currently conduct major monitoring, assessment and research programs will need to play an important role managing the comprehensive program proposed by this document. These are the programs upon which CMARP will need to be built. The comprehensive program will result from the combination of these programs and the new efforts initiated in directed response to CALFED needs. In some cases, especially where expansion or redirection of existing efforts is required to make the CMARP program work, these same agencies and organizations will need to be involved in helping to craft the changes and will need to be conducting additional work. This team will be the mechanism by which the Chief Scientist keeps all of these efforts moving in a coordinated fashion, and ensures cooperative working relationships among all of the partner organizations within the CMARP Team. The team will be responsible for helping to develop the annual work program for CMARP. Because each of the elements of the CMARP program will undergo periodic review, the membership of this team will have to be kept flexible, allowing for adding new members when a new player is identified, or dropping off an organization that no longer is playing a pivotal role.

PROCESSES

We have identified several processes by which the structures described above will carry out the functions of CMARP. Commitment to these processes is as important to the success of CMARP as the structures set up to operate them. Critical processes include

1. Control of money flow and budgeting of funds,
2. External scientific review of programs, proposals, and products,
3. Science management partnership for adaptive management,
4. Partnerships between internal and external scientists, management,
5. Data collection, research and information handling, and
6. Annual Science Conference

CONTROL OF MONEY FLOW AND BUDGETING OF FUNDS--The Monitoring, Assessment and Research Organization will need to serve the function of distributing the funds allocated for research and monitoring and accounting for the funds and the work done. To ensure accountability and to give CMARP the opportunity to have a coherent program, it will be desirable that the flow of money to CMARP for the CALFED funded portion of the program be directly from the Decision-making Body to the organization that houses and provides administrative support to the Chief Scientist. The Monitoring, Assessment and Research Organization should have the authority to make grants and contracts and should be provided with the necessary administrative support.

CMARP will have to continually undergo evaluation and adjustment to ensure that it is accomplishing its goals. This future development will have to take place within the Monitoring, Assessment and Research Organization. While the program activities should be planned on a multi-year basis, there will be an annual budgetary cycle for CALFED appropriations. CMARP will have to be translated into annual work plans (that would contain the annual increment of multi-year monitoring and research elements) each year so that it can be submitted to the Decision-making Body for review, approval and funding.

Some limitations should be set on the way the total amount of funding available for monitoring, assessment and research is spent. First, it is clear from the remainder of the CMARP report that monitoring, assessment, and research will be needed. It would be counterproductive to make dramatic shifts year to year in the proportion of funding between these two major activities. Over time, as understanding of the system increases and monitoring methods become more efficient, there may be a gradual shift to providing a larger portion of the funding to research. It will also be important to reserve some portion of the budget for "urgent management needs". From time to time, unanticipated situations will occur that may demand an immediate response by mobilizing special studies to enable rapid response to acute management issues. This should be taken into account during budget planning such that the CMARP can respond quickly to such situations without causing irreparable harm to long-term trend monitoring or multi-year research programs that have already been put into place. A goal should also be set for the proportion of funding to be spent externally to the Monitoring, Assessment and Research Organization in grants to researchers in universities, non-governmental organizations and the private sector. We propose the goal of a 50-50 split for funds expended internally and externally. Long-term shifts in funding toward this goal would be encouraged, and short-term shifts away from this goal would need to be justified.

<u>EXTERNAL SCIENTIFIC REVIEW</u>--The credibility, quality and timeliness of the external review of the science used by and produced by the CALFED program is key to achieving numerous desired attributes. It will be essential to assure that funds are effectively spent, that information produced is of high quality, that the program is responsive to management needs, and that the program does not become insular but remains open to new ideas. Such review is required at three points in the development and implementation of the program: (1) review of the overall direction and quality of the CMARP, (2) selection of research proposals and monitoring program elements, and (3) review of CMARP products.

<u>PROGRAM REVIEW</u>

External program review involves review of the overall quality and direction of the CMARP. It addresses the questions "is the CMARP providing the scientific information needed for CALFED management decisions?" "Is it asking the right questions?" Chief Scientist may wish to form one or more expert external review panels to delve in depth into questions about the program as a whole, or about a specific program element. It may be desirable, for example, to call a panel of experts on fish population dynamics to advise the Monitoring, Assessment and Research Organization and to review how well the CMARP is monitoring fish populations. The Chief Scientist may also choose to make use of intensive workshops to address a specific issue. For example, if the CMARP had funded several years of research exploring fish-X2 relationships, the Chief Scientist might want to organize a workshop involving local researchers who had been working on these problems and a number of outside experts to address whether the questions had been solved sufficiently, whether additional resources should be applied to the problem, and the directions that future research effort ought to take.

PROPOSAL SELECTION

The CMARP work program will involve work done internally by its Technical Evaluation Team, work done by agencies and organizations participating on the Science Coordination Team, work done externally by universities, agencies, non-governmental organizations, and the private sector, and projects involving collaboration among parties "internal" and "external" to the CMARP Team. It will involve a combination of monitoring program elements, research projects, and projects involving original approaches to assessment of existing data sets. The Chief Scientist will need to develop processes that ensure that ALL projects and program elements funded by CALFED would be subject to essentially the same proposal solicitation and review process, regardless of source. To do this will require instituting an objective process for the anonymous peer evaluation of proposals for new monitoring, assessment and research that is efficient and achieves broadest acceptance of the process within the CALFED community.

Research Proposal Solicitation--A list of approved management and study questions will be developed by the Chief Scientist, Technical Evaluation Team, and Science Coordination Team with input from managers, field scientists, and stakeholders. The Chief Scientists would prepare one or more Proposal Solicitation Packages designed to solicit proposals for addressing the identified study questions. The Proposal Solicitation Packages would be designed to allow for and encourage multi-year, collaborative projects. The solicitation process will also provide for projects that might be termed assessment, in that they may be focused on original analyses of existing data rather than original fieldwork. The Chief Scientist will also recommend the criteria to be used in proposal evaluation.

Proposal Review Process--It will be the job of the Chief Scientist to see that appropriate and qualified reviewers are identified and that the process is done professionally. The Chief Scientist will rely upon a two-tiered review system:

- a Peer Review Coordination Panel with members reimbursed for their time;
- a large group of pre-qualified technical experts who provide the first level of anonymous review (these reviewers will be offered honoraria for their services).

The Peer Review Coordination Panel would comprise a group of 10-15 technical experts, nominated by the Monitoring, Assessment and Research Organization. The members should be active estuarine, freshwater or watershed research scientists/engineers who have a high degree of stature, are well connected with other scientists in their respective fields, represent different specialties within these fields, and have some familiarity with the San Francisco Bay-Delta-watershed system. The Chief Scientist would ensure that Peer Review Coordination Panel members have no conflicts of interest (e.g., current or pending support from the Program).

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The members of the Peer Review Coordination Panel will be tasked with soliciting and overseeing the anonymous external (mail) review of proposals. Each member will solicit reviews by at least three experts for each proposal within his/her specialty areas, then summarize and prioritize the member's findings for presentation to the other members of the Panel. Reviewers will score the proposals, based on their scientific merit and the relevance to the Proposal Solicitation Package. When all reviews have been received, the proposals will be ranked by the Peer Review Coordination Panel based on the external mail reviews and the Panel's own evaluation. The Peer Review Coordination Panel will develop an overall prioritization of the proposals and will make funding recommendations to the Chief Scientist for his/her review of the recommendations. Until the Decision-making Body is constituted, the Chief Scientist will submit the CMARP annual work program to the CALFED Integration Panel for approval.

The Peer Review Coordination Panel will be modeled after that used by the *Exxon Valdez* Restoration Program. In the *Exxon Valdez* Program, the Peer Review Panel meets annually for several days to review the entire annual program, including progress on multi-year projects and all of the new proposals that have been submitted for funding. Reviewers serve for several years, allowing them to become familiar with the goals and management needs of the program's decision-makers and the strengths and weaknesses of the monitoring, assessment and research programs. In addition to passing judgment on individual projects as proposed, they make suggestions to augment weak but high priority projects by combining projects, bringing in additional experts to assist in certain projects, and suggesting how to redesign certain projects for future reconsideration. In this fashion they help to ensure that the proposal solicitation, review and selection process results in a coherent program of research rather than a collection of disparate projects.

<u>Monitoring Proposal Solicitation.</u>
Because monitoring elements may continue for a number of years with little change, it may be necessary to develop a different schedule for review of the monitoring elements of the program and the research and assessment elements. Thus, major elements of the monitoring program might be resolicited on a five-year cycle. The Chief Scientist would direct preparation of proposal solicitation packages seeking applicants from public and non-profit agencies, the private sector, and academia. The package would describe data collection standards, quality assurance procedures, and data delivery requirements. The Peer Review Coordination Panel would rank applicants on the basis of their qualifications and demonstrated performance, availability of required equipment and permits, the effectiveness of data collection plans, and proposed cost. The Chief Scientist would select a proposed grantee from applicants with high rankings to include within the recommended work program that would be submitted to the CALFED Decision-making Body. Grantee performance would be evaluated annually based on quality and timely delivery of data prior to renewal of the grant.

REVIEW OF CMARP PRODUCTS

Review of completed projects addresses the quality of the products produced. It asks the question, "Was the work done in a scientifically credible manner?" The ultimate process for doing this will be the peer review process that attends publication of the results in scientific journals. Another, more preliminary step will need to be provided. Getting papers published in peer reviewed literature typically takes two years or longer; CALFED managers will often want or need the information produced, including an assessment of the quality of the information, much faster than that. The solution may be a process similar to that used by the South Florida Water Management District. They have set up their own quick turn-around peer review process for all papers they produce. This primarily involves in-house reviewers (they have 90 Ph.D.s on staff), but if the material is sensitive, a large slate of pre-qualified external reviewers are available who can provide thorough peer review on a fee-for-service basis in a very short time frame. This process serves the dual purpose of providing the managers with information that they are assured is of high quality in a reasonable time frame and increasing the success of District employees in publishing their papers. This same system could be applied to any information product produced by the CMARP, even if it were not destined for publication in the peer-reviewed literature; however, as a matter of principle, we recommend that to the extent possible all of the program results be published.

<u>PARTNERSHIPS BETWEEN INTERNAL AND EXTERNAL SCIENTISTS</u>--These partnerships comprise the CMARP Team and are based upon collaborative working relationships between and among Chief Scientist, the Science Coordination Team and the agencies and organizations conducting CALFED funded AND non-CALFED funded environmental monitoring, assessment and research. The CMARP inventory of monitoring programs for the Bay-Delta and its tributary rivers shows the tremendous breadth and depth of the monitoring programs currently in existence. Many individual scientists in universities and other institutions are carrying out research relevant to CALFED needs, independent of these monitoring programs. While many of these efforts are not directly related to CALFED, a large number are producing data and information that is of tremendous value to CALFED, and may form a large portion of the comprehensive program that CMARP proposes. Upon this existing framework, the CALFED funded monitoring, assessment and research program will be superimposed. A large part of the challenge of implementing the CMARP will be to knit together these disparate programs and determine where the most value added will result from an expenditure of CALFED funding.

A network of data sharing and research collaboration and an attitude of common purpose amongst all of these organizations would serve CALFED well. The Chief Scientist and the Science Coordination Team could help to create such a network and multiply the effectiveness of their funding through a variety of means. Applying the same review process to internally and externally funded work is one such means, and providing extra-mural funding will be another. The program should seek additional means of creating incentives for participation in and cooperation with the CMARP. If this is done, a much larger virtual organization comprising much more effort and expertise than CALFED could ever pay for will materialize. If the Monitoring, Assessment and Research Organization (MARO) becomes known for its stature and professionalism, other organizations will want to associate themselves with it. It is further possible that if the MARO establishes very high standards of performance, and funds projects and programs of those agencies and organizations that meet those standards, it can create a situation in which all of the agencies and organizations working in the Bay-Delta strive to meet that standard. This would have a positive influence on the quality of all of the environmental monitoring, assessment and research done in this region. (This has been the experience of the *Exxon Valdez* Oil Spill Restoration Program.).

SCIENCE-MANAGEMENT PARTNERSHIP TO CARRY OUT ADAPTIVE MANAGEMENT--Active adaptive management, if employed by CALFED, will require a partnership between decision makers, stakeholders, managers of the natural resources, and scientists. In particular, this will mean bringing those responsible for the common programs together with the Chief Scientist and the Teams that assist him/her. This partnership is necessary because policy makers and stakeholders will have to be willing to take short-term risks with the resource, the resource manager will have to negotiate necessary agreements to acquire the resources, and scientists will have to design experiments using the resources. Successful adaptive experiments reduce long-term risks to resources by taking carefully designed, short-term risks. Adaptive experiments often focus on unusual conditions, and thereby accelerate the rate of learning beyond what would naturally occur.

DATA COLLECTION, DATA MANAGEMENT AND INFORMATION HANDLING

Data Collection, Reporting and Management--Many agencies, organizations, and individual research scientists will be collecting data and reporting it to the Monitoring and Research Organization. We do not envision that the Monitoring, Assessment and Research Organization will be managing all of this information, but it will have to set quality assurance guidelines, metadata standards, and reporting requirements. It will also need to set guidelines for making data available and may need to assist some members of the CMARP Team with this task. A certain subset of the data will need to actually be managed by the MARO. Data management is discussed more fully in chapter _______.

Likewise, we do not anticipate that all of the research needed for the program will be conducted within the Monitoring, Assessment and Research Organization. It will be the intent of CMARP to make wide use of universities, non-governmental organizations and the private sector to actually propose and carry out individual research projects, or perhaps even larger-scale, multi-year research program elements. The amount of research conducted by the organization itself, as opposed to the entire CMARP Team will depend upon how large a scientific staff is created for the organization; nonetheless, this is an activity that can go on externally as well as internally.

Data Analysis and Interpretation--Turning the data into useful information products will be one of the most important functions of the Monitoring, Assessment and Research Organization. While the Monitoring, Assessment and Research Organization will be calling on numerous members of the CMARP Team to assist in this task, it is necessary to focus responsibility for this task upon the Monitoring, Assessment and Research Organization itself. Monitoring is an expensive activity, so the more knowledge that can be derived from the monitoring the better. This means that small teams comprising experts in the relevant discipline and in exploratory data analysis and statistics should analyze monitoring data. Sufficient time will be needed for this activity, which will be directed not at solving particular problems but at querying the data for useful information. Further description of this process is provided in chapter ___(DART section of this report).

Communication of Findings--Communicating the findings of monitoring, assessment and research programs to the Decision-making Body, to the stakeholders and to the public will be a necessary function of the Monitoring, Assessment and Research Organization. Individual researchers of the CMARP team should be encouraged to communicate individual project findings. But this will not be sufficient. It will be necessary for the Decision-making Body to have help in determining which information is of sufficient quality upon which to be basing decisions. It will also be necessary for the Decision-making Body and the public to get coherent briefings on the implications of the work being done. Mechanisms for the reporting of real-time monitoring data and annual reporting of status and trends of indicators will also be needed.

ANNUAL SCIENCE CONFERENCE--Properly planned and conducted, an Annual Science Conference can enhance direct communication among scientists and managers. It can also strengthen partnerships among participating organizations and help to build public credibility. All individuals and organizations that received funding through the Monitoring, Assessment and Research Organization would be expected to participate and present their work. In addition, the Chief Scientist and others could discuss general direction of the science program, management implications of the findings coming out of the work and what is being learned about the condition of the system and the way it functions. This conference could be an annual opportunity to publicly present and explain how indicators are being used to assess "Bay-Delta Health" and what the indicators are telling us about trends in environmental condition. Such a conference might incorporate components of two existing successful and popular events: The IEP Annual Meeting and the SFEP State of the Estuary Conference.

STAKEHOLDER ADVISORY MECHANISMS--We expect that some provision will be made for stakeholder participation in the Decision-making Body that approves the CMARP budget. However, many stakeholder groups include people with considerable scientific expertise, whose contact with CMARP staff and contractor scientists will enhance the value of the program. Direct contact between scientists working for stakeholder groups and CMARP scientists should be encouraged. In addition, however, responsiveness of the overall program will depend upon the understanding of the Chief Scientist and the Science Coordination Team of the management questions that need to be addressed. A formal means, such as a Stakeholder Advisory Committee that is given the opportunity to communicate with the Chief Scientist concerning the prioritization of management questions and content of annual work plans prior to their review by the Decision-making Body would aid in this process. An

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alternate approach would be to include stakeholder representatives on the Science Coordination Team. Stakeholder-funded scientists should also be encouraged to communicate with and collaborate with CMARP-funded scientists on projects.

QUESTIONS to RESOLVE in DEVELOPING A CMARP ORGANIZATIONAL STRUCTURE

It is our hope that the basic elements discussed above will fit into any number of structures that might be formed for the overall governance of the CALFED program. There are a number of decisions concerning the institutional structure that the workgroup discussed, and which we proposed to those we interviewed. Largely because of the uncertainty that exists concerning the eventual structure for the overall CALFED program and its decision-making process, we were unable to reach conclusions on some of these questions. The following questions represent areas where the views of reviewers would be most welcome.

<u>What is CMARP's Relationship to CALFED?</u> We have described CMARP as the science arm of CALFED. This implies that the relationship between CMARP and CALFED is essentially a partnership. It is a partnership intended to promote science-based decision-making and an adaptive approach to managing the Bay-Delta System. We have, therefore, tried to describe elements of an organization that would both be accountable and responsive to CALFED, yet be able to carry out monitoring, assessment and research in a fairly independent manner. This is not the only relationship that could be established. It is possible to create a monitoring and assessment program that is imbedded within the CALFED Decision-making body and that only responds to specific tasks generated by program managers. It would also be able to create a science program that was independently funded and therefore completely independent of the CALFED management structure.

<u>To Whom or what does CMARP Report?</u> Because we are not certain how the CALFED program in the future will carry out decision-making, it is difficult to suggest exactly whom the Chief Scientist and the rest of the CMARP institutional structure should report. Most workgroup members felt that the Chief Scientist should be hired by and attached to some organization such that he or she did not have to personally deal with all of the administrative functions that attend to grant-making and contract management. It is necessary to define a direct relationship between the Chief Scientist and the highest Decision-making Body of CALFED, including whether it is that body that is responsible for his/her hiring and firing. This is the only way that CMARP can act as the science arm of the CALFED program, and act in partnership with CALFED in promoting an adaptive approach to managing the Bay-Delta system.

Some stakeholders felt strongly that the program should be closely attached to and responsive to the Ecosystem Restoration Authority. If the common programs are carried out as separate independent programs with different decision-making bodies, however, then it cannot be lodged within each of them, and should be independent of any of the common programs.

What monitoring and research functions should be centralized, and to what extent? The original charge to IEP, USGS and SFEI was to design a program that addressed all of the common programs. That does not necessarily imply that one overall institutional structure should address all needs. A few of the stakeholders questioned felt strongly that CMARP should concentrate on the environmental questions, and not deal with issues such as water transfer and water efficiency. They expressed the view that these latter concerns should be monitored by different organizations from the one primarily concerned with ecosystem conditions. Many felt strongly that there should be a monitoring program created specifically to serve the needs of an Ecosystem Restoration Authority. Most of the workgroup felt that there would be benefits to having one comprehensive monitoring, assessment and research program. They argued that many of the common programs have interrelated and overlapping information needs, that activities proposed to promote the objectives of one common program might have adverse effects in others, and these need to be assessed comprehensively.

Is a new agency or organization needed to implement CMARP? A number of stakeholders queried believed strongly that a new organization should be established. Workgroup members were divided on this point. It was felt by workgroup members that a new scientific culture needed to be established, and this would be easier to do with a new organization at the core of the effort. But with the inclusion of the position of Chief Scientist and a commitment to extensive external and peer review, it could be accomplished. Whether or not a new organization was formed at the core of CMARP, all felt that the collaboration among the larger CMARP Team was key to success of the overall program. If a new organization is set up, care should be taken to make this organization one that enhances, rather than competes with existing programs.

Chapter VIII. IMPLEMENTATION OF CMARP

CMARP will continue to evolve with the CALFED program. Prior to CALFED's record of decision, an implementation structure for CMARP must be developed as part of the organizational structure needed for implementing the CALFED program. During this period a few high priority tasks will begin, and monitoring and research program designs will be refined and focused as the actions of Stage I of CALFED implementation stabilize. Finally, CMARP program costs need to be established, and program financing needs to be solidified so that CMARP can be implemented. This chapter describes activities that will take place during 1999 toward these ends.

A. Developing a CMARP implementation structure

In the absence of a CALFED implementation structure, Chapter VII has focused on defining organizational ingredients and outlining how those ingredients might interact with resource managers, decision makers, and stakeholders. As a CALFED implementation structure becomes defined during 1999, a permanent structure for CMARP must be created. While early implementation tasks are carried out by staffs of existing entities, a search for a chief scientist needs to begin.

A search committee composed of agency, academic, and stakeholder scientists needs to be appointed by the CALFED Policy Group to undertake a national search for a chief scientist. The search committee would develop and prioritize a list of at least 10 qualified individuals in collaboration with the National Academy of Sciences. The prioritized list would be presented to the CALFED Policy Group for selection of a shorter candidate list. Hiring negotiations would commence thereafter with the objective of having a chief scientist in place just after a CALFED record of decision.

Prior to the record of decision a steering committee will continue to manage CMARP implementation and refinement activities. This steering committee will report to the CALFED Management Team and Policy Group through the CALFED Executive Director. The steering committee will designate an agency person and appropriate support staff to direct the program during this interim period. The steering committee will continue to coordinate CMARP activities with CALFED program managers and agency staffs.

Funding of CMARP is needed during 1999 to manage the program, to implement a few high-priority tasks, and to refine monitoring and research program designs. Along with funds left over from CMARP's initial allocation, about $400,000 will be necessary to manage and refine the program during 1999. The costs of early implementation tasks described next have yet to be estimated, but will probably cost a few million dollars.

B. Implementation Tasks for 1999

In the absence of a chief scientist, a subcommittee of the CMARP Steering Committee will oversee finalization of water-quality- and ERP-related research questions by spring, 1999 and will implement the anonymous peer review process described in Chapter VII. Prior to release the research questions and Proposal Solicitation Package will be reviewed by the Ecosystem Roundtable and approved by the Policy Group. After the solicitation, the peer review process will be used to provide the technical reviews of proposals, and to develop a set of rankings. These rankings will be provided to the existing CALFED Category III Integration Panel for selection and funding of projects before the end of September 1999.

In addition, high priority monitoring and directed studies were [*are being*] selected based on three criteria:

- information needed early to implement CALFED;
- information needed by more than one CALFED common program; and
- needed information that can be derived from existing data.

The selected tasks are [*The Steering Committee is still working on this list. Examples of tasks that might be selected include*]:

- Diversion effects on fish. The salvage of threatened species at the export facilities demonstrates that the facilities are a mortality factor. How important the facilities are relative to other mortality factors, however, is not completely clear. The recent work of DEFT and the No-Name group suggest a more rigorous analysis of salvage at export facilities to better define flexibility of project operations. In addition, three proposed Stage I fish screens need to be evaluated. CMARP would establish teams to develop monitoring and analysis efforts....

- Municipal source water quality. The recently-convened expert panel on bromide (and organic carbon) in drinking water described the needs of more than 20 Million Californians for drinking water exported from the delta. As these needs increase, changes in drinking water regulations and population increases will probably require both more advanced water treatment processes and better source water quality. Thus, how to reduce bromide concentrations and disinfection by-product precursors in exports is becoming an increasingly important issue. The expert panel, urban water purveyors, and CALFED and CMARP staffs have recognized the need to answer several questions to assess the feasibility of reducing source water concentrations during Stage I of implementation. A committee of selected agency and stakeholder personnel will be convened to reach consensus on the questions and priorities for a proposal solicitation package by spring, 1999. *[Although there may be some limitations on restoration coordination funds, it is anticipated at least that funding assessment of organic carbon changes resulting from land conversion to wetlands would qualify for funding.*]

- Marking hatchery salmon. A constant fractional marking program of salmon smolts released from Central Valley chinook hatcheries will be initiated to permit evaluation of hatchery contributions to spawning escapement and ocean and inland recreational fisheries....

- Delta topography and bathymetry. New topographic and bathymetric maps of the entire delta are needed because land surface in the delta is subsiding, because levee construction and maintenance continues to alter the profiles and elevations of the levees, and because delta channels continue to adjust hydraulically to altered hydrology and sediment inputs. These maps are needed for implementing the delta levees program, for planning through-delta channel modifications and delta wetland restorations, and for improving delta water-quality-simulation models. Only partial maps have been done at different times in the past because of the expense of standard techniques. New technologies combined with recent establishment of about 100 GPS benchmarks, however, promise to lower the cost of doing accurate mapping. A committee of selected agency and stakeholder personnel will direct a short-term study (about 3 months) of the feasibility of using LIDAR (Light Detection and Ranging) for topography and shallow water bathymetry, and multi-beam sonar for deeper bathymetry, and for tying their data to the new GPS benchmarks. Given that using these techniques is feasible and those projected costs are affordable, the committee will develop mapping contracts for CALFED approval during 1999. The committee will also set up a continuing process to update locations and elevations of the GPS benchmarks.

- Documenting and assessing effects of aquatic species introductions. CMARP will take an active role in documenting introductions and determining the ecological effects of these introductions. The efforts will be closely coordinated with other programs in IEP, SFEI, and the Coastal Committee of the Western Regional Panel of the National Aquatic Nuisance Species Task Force....

- Review of streamflow network. All common programs have identified needs for streamflow information, and a consolidated assessment of program requirements is needed to specify what the streamflow measurement network in the Central Valley and the delta should be. This assessment is particularly important in light of the long-term decline in funds for stream gaging in agency budgets. During 1999 a multi-agency committee will be appointed to undertake this review with the objective of identifying gage sites and additional funding needs prior to CALFED's record of decision.

C. Refinement of CMARP elements during 1999

All monitoring programs still need refinement, but some programs require more than others. Monitoring to meet the needs of the Conservation Strategy has only been described in the most general terms and cannot be developed further until the Conservation Strategy has been completed. Design of mitigation monitoring awaits selection of actions that require mitigation. The Watershed Management Program needs more specificity for CMARP to design and implement monitoring, and much more stakeholder involvement will be needed to help develop details. Monitoring and research for the rest of the common programs have been developed to a significant degree, and need refining as described below. In addition to these refinements, a significant amount of integration of these almost-independent program designs needs to be completed.

1. Refinements of ERP monitoring program. Continued development of the ERP monitoring recommendations is needed to address general issues that cut across all the CMARP work teams, and refinement of specific monitoring recommendations within each work team.

The general issues that need further development for CMARP to proceed with implementation include:

- refining conceptual framework for indicators,
- integrating identified monitoring elements into conceptual framework,
- formalizing process for indicator selection, refinement and implementation, and
- completing integration of CMARP monitoring elements with CALFED's Conservation Strategy.

The following table groups the CMARP ERP work teams based on the need for additional refinement of their monitoring recommendations prior to implementation.

Table 8.1. Summary of the ERP CMARP work team accomplishments and tasks needing further development for implementation of recommended monitoring elements.

Group	Work Teams	Accomplishments	Additional Steps
1	• Hydrodynamics • Chinook Salmon & Steelhead	• Identified what needs to be monitored & why • Linked to existing monitoring programs • Recommended new monitoring & modifications to existing programs • Specified locations, timing and methods for new monitoring • Prioritized recommendations • Estimated costs	• Obtain outside review • Evaluate monitoring in relation to CALFED priorities & actions • Determine process for initiating new monitoring
2	• Fish-X2 • System Productivity:Lower • System Productivity:Upper • Central Valley Steelhead • Delta Smelt • Non-Indigenous Organisms • Benthic Macroinvertebrates • River Resident Fish Species • Fish in Shallow Water Habitats	• Identified what needs to be monitored & why • Linked to existing monitoring programs • Recommended new monitoring & modifications to existing programs • Provided some general guidance on locations, timing & methods for new monitoring	• Complete Group 1 steps + • Develop greater detail on location, timing & methodology • Prioritize recommendations • Estimate costs
3	• Shallow Water Habitats • Fluvial Geomorphology & Riparian Issues	• Identified what needs to be monitored & why • Provided some general guidance on locations, timing & methods for new monitoring	• Complete Group 1 & 2 steps + • Link to existing monitoring programs

2. Refinements of water quality program. The water quality monitoring and research program will be refined in the following ways:

Refinement of Sampling Strategies, Sampling Sites, Sampling Methods, and Archival of Biological Organisms. The strategies on which the different elements of the monitoring plan are based need to be specified. The sampling strategies (such as stratified random sampling and probabilistic sampling) depend upon the objectives of the monitoring. Most existing programs sample at fixed sites on a routine schedule. The sample sites are biased by the objectives of the particular existing monitoring programs. The sampling strategies and sample sites need to be reviewed based on the CMARP objectives of monitoring.

Sampling sites need to be refined based on the sampling strategies. There must be method development for sampling constituents previously not sampled, or for which differing methods of analysis exist. Also, there must be ongoing review of new methods of analysis, as they become available. There must also be review of tidal influence on water quality sampling. A policy for storage and archiving of biological samples needs to be developed.

Refinement of Specific Elements of the Water Quality Monitoring Plan. (See referenced appendices for more detail.)

- Refine sampling strategy (including identifying species and locations where concentrations of organochlorines raise concern for human or wildlife health) for organochlorines in fish tissue. Take recommendations from the chlorinated hydrocarbon work group of the SFEI Regional Monitoring Program and incorporate into CMARP (Contaminants).
- Identify sediment-sampling sites in the Delta (Contaminants).
- Analyze results of pilot fish tissue studies in the San Francisco Bay, Sacramento watershed and in the Southern Delta (Contaminants).
- Conduct necessary preparatory work for the pesticide-monitoring program. This includes developing better access to the Department of Pesticide Regulations Pesticide use report (PUR) database, developing pesticide analytical screens to measure these pesticides at biologically meaningful detection limits, and analyze critical fate and effects information for the different pesticides in the monitoring program such as duration of exposure, frequency of exposure, and bioavailability.
- Develop a tributary monitoring program. The Sacramento River Watershed Program has been involved in three pilot tributary monitoring programs (Mill Creek, Big Chico Creek, and Deer Creek). Tributary monitoring is important for water quality monitoring and as a means to educate local stakeholders regarding monitoring methods and water quality issues (Sacramento Region appendix).

Quality Assurance and QA Intercalibration. The ability to combine data from several programs is essential to the success of CMARP. To successfully do so will require a strong QA/QC program with participation of all monitoring programs. Contaminant concentrations should be measured to levels needed to assess compliance with Water Quality objectives and to evaluate their potential for ecological effects. This principle is currently being used in the Regional Monitoring Program and the Sacramento Regional Watershed Program (see Contaminants appendix) and their data quality objectives could be adopted as a start.

It is not necessary to require that standard methods of sampling, handling, or analysis be conducted. However, performance standards are critical and should be based on the goals and objectives of the program stated above. That approach will require a strong QA program that includes intercalibration of sampling gear, the splitting of

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samples among participating laboratories, analysis of standard reference materials, etc. Meeting the QA standards may require technology transfer to laboratories that are not yet capable of meeting those standards that could be supported by CMARP.

Immediate implementation of QA and intercalibration exercises among all existing programs is recommended so that when monitoring does begin, comparability will be assured.

Integration of Monitoring. Further integration of the water quality monitoring program with the Ecosystem Restoration, Delta Levees, Storage and Conveyance, Water Transfers, Water Use Efficiency and Watershed programs. For example, benthic monitoring will be conducted to evaluate ecosystem characteristics, ecosystem productivity and contaminant effects. This monitoring will need to be well coordinated to address these multiple purposes.

Development of Indicators. Indicators of system productivity and contaminant effects need to be developed. Many of the measurements recommended for monitoring are commonly used as indicators. Contaminant concentrations are used to indicate the potential for adverse ecological and /or human health effects when compared to regulatory water quality objectives or criteria. However, whether the exceedance of a regulatory criterion actually predicts ecological or human health risk has not been rigorously tested in the Bay-Delta.

Similarly, there are sediment quality guidelines and tissue residue (bioaccumulation) guidelines that can be used as indicators of the potential for impacts. However, most sediment and tissue guidelines hold no regulatory status and their efficacy as indicators of impacts are debated. Aquatic and sediment toxicity testing is considered to be an indicator of the potential for ecological impacts. But, again, the relationships between laboratory tests using nonresident species and actual ecological impact have not been well studied.

Identification of Who Will Conduct the Monitoring. Further work on identification of who will conduct the monitoring needs to be done. How existing programs can be modified to meet CMARP needs must be identified.

Monitoring Cost. Costs for water quality monitoring have not yet been identified. Dependent upon the number of stations, frequency of sampling, funding from other programs, etc., the costs will vary greatly. As the monitoring program becomes more focused, costs of monitoring will need to be identified.

3. Refinements of the levees program.

. . .

4. Refinements of water transfers and water use efficiency programs. During 1998 many monitoring networks were inventoried that may provide data important for evaluating the effects of water transfers. However, assessment of the suitability of existing networks for CALFED purposes has just begun. 1999 will be a critical year for assessment activities.

The suitability of more 10,000 groundwater-level observation wells in existing networks for use as part of a CALFED regional groundwater-level monitoring network will be evaluated. The suitability of more than 5,000 previously sampled wells for use as part of a CALFED regional groundwater-quality monitoring network will be evaluated. Groundwater level and quality network assessments will consider the period of record, well construction details, well location, frequency of measurement, interagency coordination of monitoring, and digital availability of monitoring data. The feasibility of using the Environmental Agency's STORET database as a surrogate network of groundwater quality information could be evaluated. The feasibility of reactivating sediment compaction recorders constructed decades ago will be determined. Coordination of new horizontal and vertical geodetic control networks in the Central Valley will continue.

5. Refinement of the watershed management program. Monitoring at smaller scales – scales of particular interest for adpative management feedback – depends heavily on local participation and must serve needs of local decision makers and the public. Refinement of objectives and specific implementation plans for monitoring of biophysical parameters at these scales will require full participation of local stakeholders. Stakeholders have already identified economic and social aspects of watershed management as central to the Watershed Program, but have not expressed a consensus view of how these issues should be addressed in the monitoring program. Upcoming work will focus on organizing stakeholder input into defining a conceptual framework for monitoring of economic and social elements, as well as working with stakeholders to refine monitoring plans for all plan elements at smaller scales.

6. Refinement of indicators and data assessment and reporting mechanisms. Existing reporting mechanisms already provide a lot of useful information, but some areas of additional development could include:

- refining the list of physical, chemical, and biological indicators, and developing management-oriented indicators. Most of the indicators developed by the workteams qualify as base level indicators as described in figure 2 of Chapter 6. Development of intermediate, or management-oriented, indicators has only begun. These indicators will become defined better as Stage I actions become more firm.
- creating an online list of known correlations among monitoring variables being collected, and developing a routine process for checking new data to see if they

fit the correlations. This process performs a rudimentary check for trends in data. If correlations appear to be changing or deteriorating, managers and scientists would be alerted to the change. Over time, much more powerful trend detection methods can be added to the list.

- creating an online list of present water quality and biological standards, and a routine process for demonstrating compliance. The compliance demonstration provides an assurance on a publicly accessible web page that projects are being operated to meet standards. Additional standards, such as levee or groundwater standards, can be added as they are developed.
- developing an online list of non-native species introductions and literature on life histories of these species. The database would be established to document introductions of non-native aquatic species in the bay-delta and Central Valley streams. It would also include life history information on the species, and would eventually summarize their ecological effects – e. g., organisms supplanted and effects on the predators of those organisms.
- publishing status and trends of important data for the previous year. An annual status and trends report, similar to the spring IEP newsletter, but also including streamflow, groundwater levels in the valley, levee activities, habitat restored, environmental and drinking water quality, ... would be published in the spring of each year covering the previous water year (October to September).

7. Developing active adaptive management partnerships. CMARP is presently designed to fulfill the needs of a traditional passive adaptive management program. Although this program will reduce scientific uncertainties over a period of decades, CALFED needs to reduce key uncertainties at a more rapid rate to meet program objectives. Using a more active form of adaptive management, CALFED can accelerate the learning process.

Active adaptive management as defined by Holling (1978) and Walters (1986), and as recommended in the ERP Strategic Plan (1998), involves carefully designed and monitored management actions that are valid scientific experiments. The purpose of the management actions is to reduce uncertainties by demonstrating how and why natural resources respond to those factors that affect them.

For example, some knowledge usually exists already about causes and effects, but knowledge about infrequent or extreme conditions is often limited or non-existent. Such unusual conditions, however, simultaneously can be circumstances when risks of irreversible resource changes are greatest and ideal times for observing important effects. Active adaptive management can create opportunities to document and evaluate unusual conditions in a limited context, thereby accelerating learning and reducing long-term risks.

As implied, however, active adaptive management necessarily involves taking limited, short-term risks with resources. In addition to the practical problems of acquiring control of enough resources to create unusual conditions, active adaptive management can conflict with regulatory and management policies, which are usually designed to avoid risks. These circumstances partially explain the infrequent use of active adaptive management (Walters, 1997).

Thus active adaptive management, if employed by CALFED, will require policy-level recognition of scientific uncertainties and acceptance of resource risks. CMARP envisions active adaptive management as a partnership among policy makers, stakeholders, resource managers, and scientists. Given Policy Group agreement, CMARP will help develop partnerships to design active experiments.

D. Estimating Program Costs

An expensive monitoring and research program is a natural consequence of asking scientists to list monitoring and research needs for a system like the Bay-Delta and Central Valley about which there is a lot of uncertainty. With sufficient organization and review, a valid CALFED research program of a size similar to the U. S. space program could be developed because of these uncertainties. Although such a program would have significant short- and long-term benefits, developing a political consensus to fund one appears unlikely. Thus some other approach to establishing program limits is needed.

One approach is to task resource managers with deciding how much of a program to spend on monitoring and research. Such an approach puts monitoring and research in competition with operation of projects and construction and maintenance of facilities, which can easily result in monitoring and research funding instabilities or chronically inadequate programs. For these reasons support of a monitoring and research program is more properly defined as a continuing policy issue.

A second approach is to rank monitoring and research based on criteria that emphasize perceived management needs. The CMARP steering committee asked the teams to focus their attention on the needs of the CALFED common programs and related agency programs. Although the needs of the common programs remain somewhat volatile, this focus led to some ranking within teams. The steering committee has avoided rankings among teams, however, because deciding how to make trade-offs among programs is inevitably a subjective and continuing process that must involve agencies and stakeholders. More importantly, rankings still do not determine a total program cost.

Thus, a third approach is to limit the cost of the monitoring and research program to a percentage of the total CALFED implementation program. Then an initial program can be created based on this limit, the assumption that existing agency programs will continue, and a to-be-established set of monitoring/research priorities among the common programs and the Storage and Conveyance program. [talk about the process to create priorities among the programs.]

CMARP recommends that an approximate annual percentage between 10 and 20 percent ($65M-135M) of the CALFED program, be agreed to as a preliminary figure including present programs. A program much less than 10 per cent (like the sum of present programs, about $28M) appears unlikely to meet CALFED's long-term needs, whereas a program above 20 per cent would probably be hard to justify and sustain without major early results. Outside of adjustments for inflation, the actual percentage would vary as the program evolves.

E. Financing CMARP

Beyond agreement on a total program cost, CMARP needs assurance that funding for existing monitoring and research programs will continue at inflation-adjusted current levels of spending. These programs include those listed in Table __ [Inventory section, table 2]. Although agencies are under no obligation to CALFED to continue these programs at current levels of effort, future changes to these programs should trigger reevaluation of CMARP's level of effort.

In addition, an inflation factor is needed to sustain the level of effort agreed on for CALFED's monitoring and research activities supplemental to these programs. More substantial adjustments to this program should be contemplated as the program is reviewed periodically.

Finally, public funds are probably a primary source for CMARP because everyone benefits from the information generated. Category III and CALFED projects requiring mitigation monitoring will be a secondary source. Which agencies will eventually receive the State and Federal appropriations that fund CMARP depends on what organizational structure becomes responsible for implementing the common programs and the preferred alternative. Assuming that a decision will be recorded during 2000, it is recommended that the California Department of Water Resources and the Bureau of Reclamation budgets temporarily include funding of CMARP implementation for fiscal year 2000.

CMARP Workteam Appendices

I. Proposal for the Development of a CMARP (April 24, 1998)
II. Glossary of Terms
III. Membership of CMARP work teams
IV. CALFED Goals and Objectives (6/15/98)
V. Conceptual Framework (7/17/98)
VI. List of existing monitoring programs
VII. Monitoring Program Design

A. Bay-Delta Fish X-2 (10/26/98)
B. Shallow Water Habitats- Geomorphology Emphasis (10/16/98)
C. Fishes in Shallow-Water Habitats (no date)
D. Hydrodynamics and Sediment Transport (no date)
E. System Productivity- Small Invertebrates (10/23/98)
F. Bay-Delta Upper Level System Productivity- (no date)
G. Delta Smelt (10/29/98)G. Salmon-Bay-Delta region (9/9/98)
H. Salmon- San Joaquin Region (10/17/98)
I. Salmon- Sacramento Region (10/9/98)
J. Resident Fish (11/6/98)
K. Steelhead (11/2/98)
L. Fluvial Geomorphology and Riparian Systems (10/4/98)
M. Benthic Invertebrates (11/3/98)
N. Water Quality-Contaminants (11/2/98)
O. Water Quality-Drinking Water (11/4/98)
P. Water Quality -Sacramento Region
Q. Water Quality- San Joaquin Region (10/19/98)
R. Subsidence on Delta Islands (no date
S. Water Transfers (10/7/98)
T. Water Use Efficiency (10/1/98)
U. Watershed Management (10/14/98)
V. Delta Levees (10/1/98)
W. Data Management Process
X. Data Analysis and Reporting (9/30/98)
Y. Category III Monitoring Institutional Process (no date)
Z. Focused Research Program (11/2/98)
AA. Institutional Structure for CMARP (11/2/98)

LESTER A. SNOW
EXECUTIVE DIRECTOR